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Chesapeake Science

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Chesapeake Science

CHESAPEAKE SCIENCE is devoted to presenting the results of research and management studies dealing with the natural resources of the Chesapeake Bay region and other technical papers on related subjects.

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Introduction

Publication of results and of their interpretations are essential to completion of scientific research. CHESAPEAKE SCIENCE has been initiated because we believe it will encourage competent research and permit printing and distribution of many good papers which might otherwise be lost in the files of individuals.

Unpublished research is a selfish and usually sterile thing. The investigator has had the deep personal reward of the quest, of the unexpected new interpretations and challenges, and of the knowledge that he alone knows a new fact or comprehends a new concept. Unless his efforts and the yield from them are communicated to others, however, most of the benefit of his intelligence, effort, and thoughtful interpretation is lost.

After research has been conducted, publication adds many additional values. The work is subjected to the searching, and sometimes jarring, analysis and review essential to preparation of a manuscript which is to be placed before the critical eyes of the profession for evaluation. Other investigators gain the marvelous stimulus of new ideas, and the stepping-stone provided by research accomplishment. Those who need to apply the result of research to practical problems (and these are often those who paid the costs of the investigation) are furnished an essential tool in the solution of their problems.

There are existing avenues for publication of the results of research conducted on the natural resources of the Chesapeake Bay watershed and related areas. Should a new regional journal be added to the impressive list of existing outlets? Obviously, we believe so. We are convinced that there are many fine and useful papers which would not be properly placed in the national and international journals, because their application is essentially regional and not universal. These could be, and sometimes have been, issued as separates, but this method lacks continuity and usually produces a sadly inadequate distribution. Others, though acceptable to national journals, sometimes are of such nature that much of their usefulness may be lost through delays in publications occasioned by extensive backlogs of previously submitted manuscripts.

We propose to publish short papers and notes of good quality, and to make them available as soon as possible to scientists, students, teachers, resource managers and interested laymen throughout the Chesapeake region and in other appropriate areas. We particularly solicit participation by the research centers, colleges, universities and scientific societies of this region and hope they will contribute manuscripts. Specific suggestions to possible contributors are included in the "Instructions to Authors" at the end of this volume.

The watershed concept inherent in the selection of the pertinent region may serve two constructive purposes. It will constantly remind all of the readers of CHESAPEAKE SCIENCE of the fundamental and irrevocable interrelationships existing among the resources of the area. It may also underscore and emphasize the universality of scientific concepts and research techniques.

Our sights are set high, because we wish simultaneously to stimulate investigators, aid professional colleagues, and serve those who can apply the results of research. If we can succeed in these, the considerable effort of birthing a new journal will be well spent.

L. Eugene Cronin

Maryland Department of Research and Education,
Solomons and Annapolis, Maryland.

Temperature and Salinity of Surface Water at Solomons, Maryland[1,2]

G. Francis Beaven

ABSTRACT

Daily temperature and salinity values of surface water at Solomons, Maryland, midway down the Chesapeake estuary, have been tabulated and averaged for a 20-year period. Fluctuations are shown by graphic representation of the monthly means and ranges. Relationship of the Solomons data to those for other parts of the Chesapeake is discussed.

Water temperatures have varied from 31° to −0.8°C and do not deviate widely from the average annual pattern. Seasonal 20-year means are: winter 4.3°, spring 11.9°, summer 25.6° and fall 18.2°. The freezing point was reached during 4 years of the 20-year base period.

The seasonal salinity pattern is rather variable with minima usually reached in late spring and maxima in late fall. Long-term trends show a much greater range than do fluctuations associated with stage of tide, local precipitation and wind-generated water movements. Extreme values are 20.4 and 5.4 parts per thousand. Seasonal 20-year means are: winter 14.8, spring 11.4, summer 12.3 and fall 15.7.

Introduction

Changes in the temperature and salinity of estuarine waters exert a marked influence upon the presence and activity of many species of plants and animals that inhabit such environments. In the Chesapeake Bay both salinity and temperature vary through a considerable seasonal range and also from year to year. A knowledge of such variations at a given point offers a useful means of relating certain biological and physical phenomena to accompanying temperature and salinity conditions. Solomons is particularly well located as a point of reference that is representative of the median of conditions occurring over a major portion of the Chesapeake estuary.

The purpose of the present paper is to supplement previously published data by making available in convenient form daily surface temperature and salinity values at Solomons. Averages for the twenty-year period 1938–1957 are offered as a good approximation of normal conditions to which unusual departures may be referred.

[1] Special reprints of this article containing appended tabulated daily values are available.

[2] Contribution No. 132, Maryland Department of Research and Education, Solomons, Maryland.

A number of publications have dealt with Chesapeake temperatures and salinities but most cover a comparatively short period of time or are from widely separated observations. An exception to this are tables published by the U. S. Coast and Geodetic Survey containing data from the various tide stations. These furnish the longest and most continuous data for the Chesapeake area. The data used herein have in part been taken in connection with the operation by the Laboratory of a tide station for the Coast and Geodetic Survey, with density values expressed as salinities, and are supplemented by additional pier samples, hourly salinity runs, vertical sampling and continuous thermograph recordings.

An extensive analysis of the data has not been attempted. Calculations have been made of 20-year daily averages, 20-year monthly averages, and of yearly and monthly means. As a convenient method of showing gross changes the monthly means and ranges are shown graphically (Fig. 1). Smoothed reference curves have been derived from a moving ten-day average of the twenty-year daily means. Two additional years of observation have been recorded since the long-term means were cal-

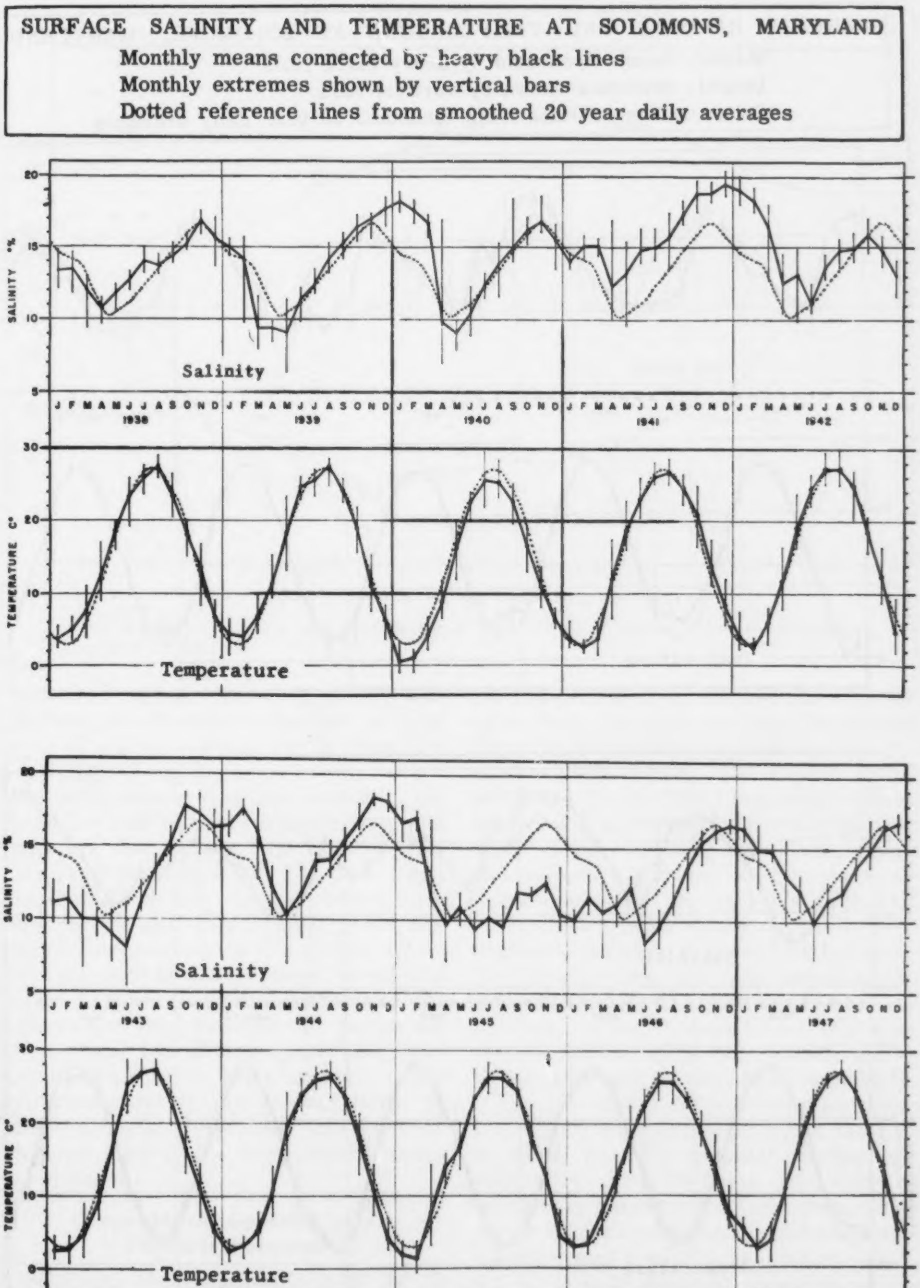

Fig. 1A.—Surface salinity and temperature recorded in the Patuxent River at Solomons, Maryland from 1938 to 1947.

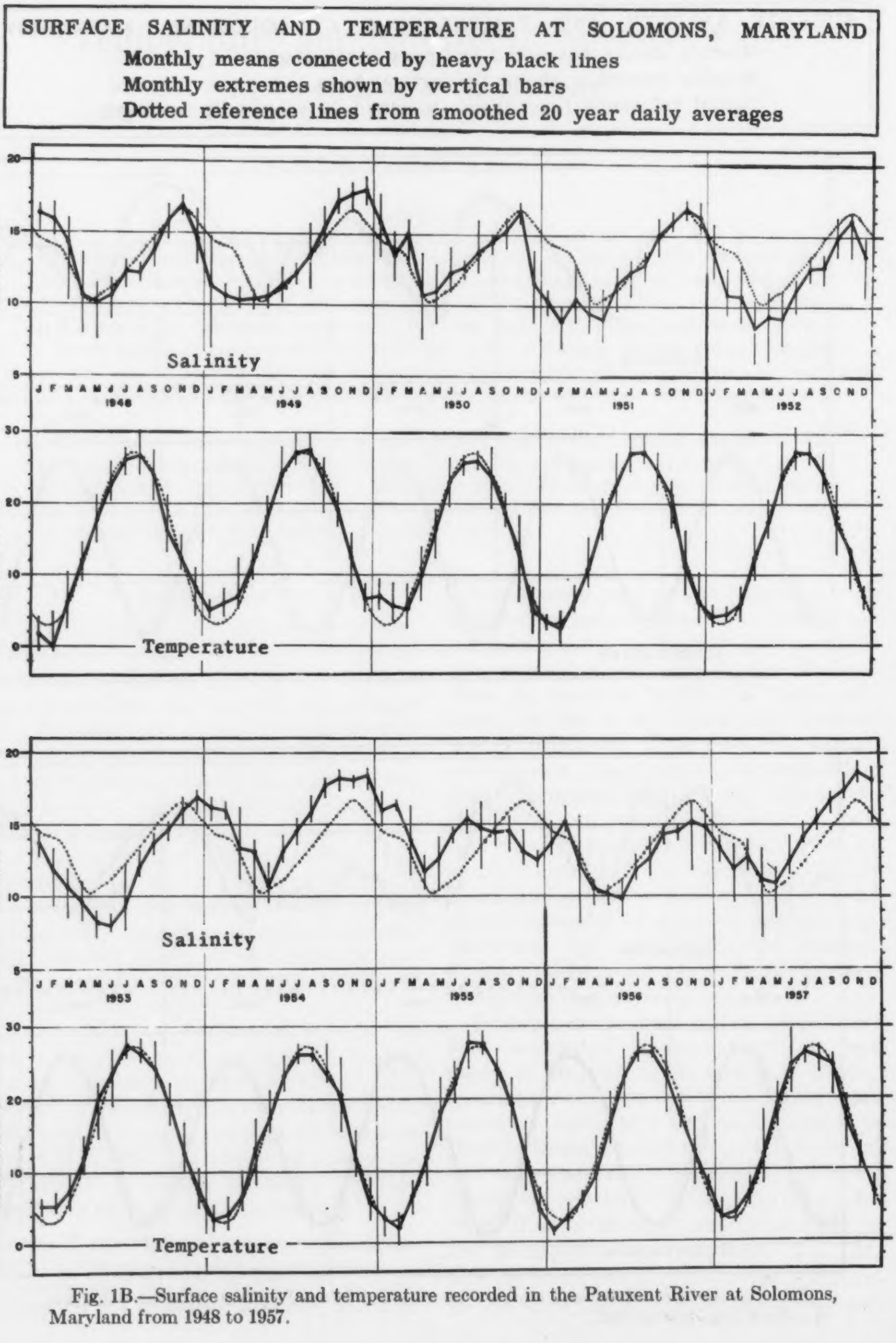

Fig. 1B.—Surface salinity and temperature recorded in the Patuxent River at Solomons, Maryland from 1948 to 1957.

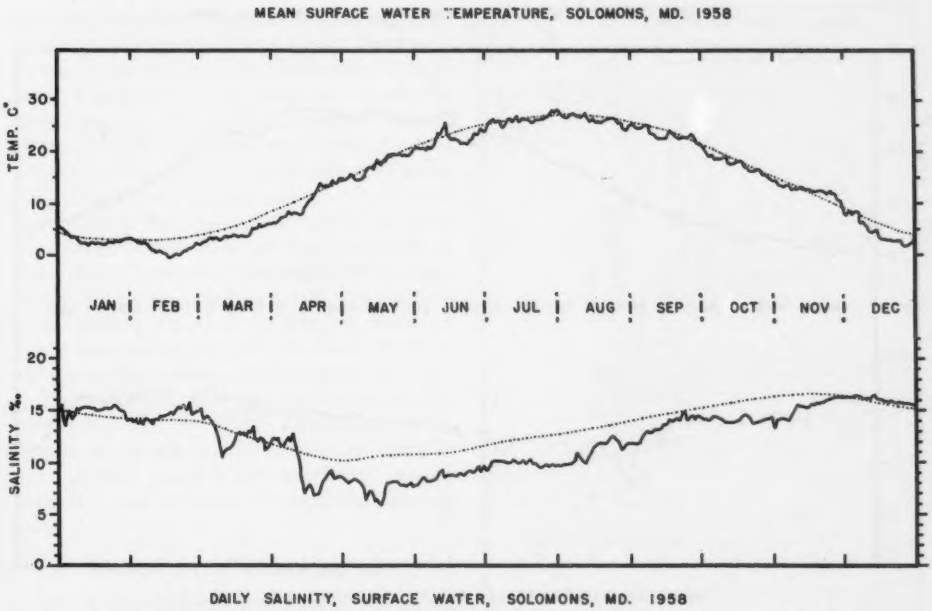

Fig. 2.—Surface salinity and temperature recorded in the Patuxent River at Solomons, Maryland during 1958.

culated. These are shown by graphs that give details of daily variations as they occur in a cool wet year and a warm dry year (Figs. 2 and 3).

Grateful acknowledgment is made to the numerous staff members whose careful and continued observations have made the accumulated data available. The U. S. Coast and Geodetic Survey has furnished calibrations for the hydrometers used for the tide station observations and supplied tables for reduction of the readings to salinity values. Appreciation is expressed to the Chesapeake Bay Institute for permission to reproduce two of their charts that show salinity distributions in the bay. Mrs. Leone Williams prepared and checked tables of tabulated data. Miss Sara Jane Zahniser prepared most of the basic graphs reproduced herein.

Geographical Location and Physical Features

Solomons, Maryland, latitude 38° 19′ N, longitude 76° 27′ W, is partly situated on a small island within the mouth of the Patuxent River, about one and three fourths miles from its entrance into Chesapeake Bay. The surrounding brackish waters support valuable fisheries for oysters, clams, crabs and finfish. The Chesapeake system is typical of a drowned river-valley estuary of the north temperate zone. Temperature and salinity conditions at Solomons are representative of the mid-bay area and fluctuations here are closely related to those that occur throughout most of the bay area. The distance from the river mouth to the head of the bay, and to the entrance into the ocean at the Virginia Capes, is a little over 80 nautical miles (92+ statute miles) to the north and to the south respectively.

The Patuxent River is a broad and relatively deep estuarine tributary of the bay in which the tidal influence reaches upstream for about 50 miles. The width of most of the lower portion varies from about one to two miles for the first 20 miles and then decreases gradually to about one quarter of a mile some 30 miles above its mouth. A constriction occurs just above Solomons where the width is less than half

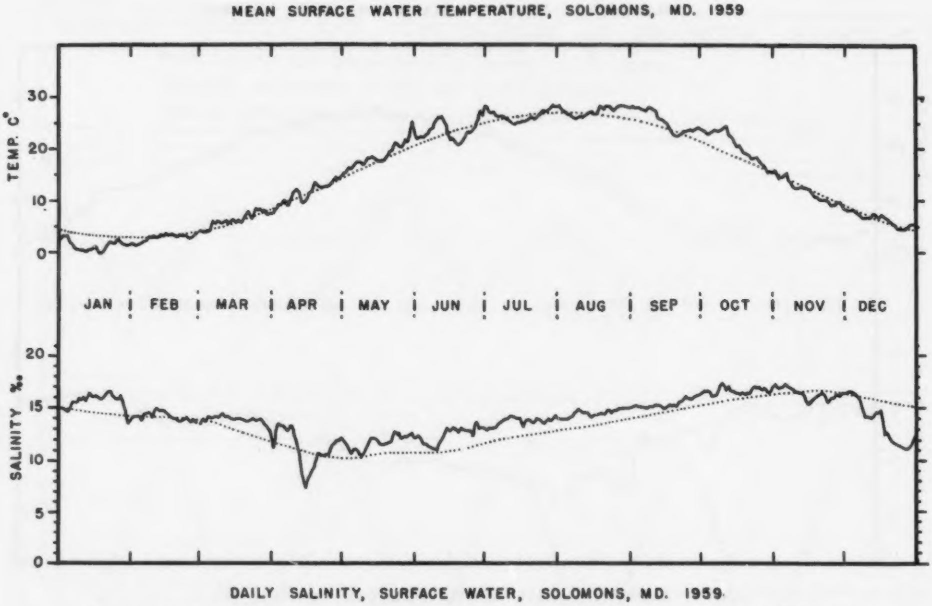

Fig. 3.—Surface salinity and temperature recorded in the Patuxent River at Solomons, Maryland during 1959.

a mile, but here the water is deeper than in other parts, well over 100 feet in mid-channel, and tidal velocities exceed those in other portions of the lower river. Mean tidal amplitude is 1.2 feet at Solomons and increases upstream to 2.5 feet at Nottingham, approximately 45 miles from the river's mouth (Tide Table 1960). The drainage basin of the river is relatively small, about 960 square miles, comprising approximately 1.3 percent of the entire Chesapeake basin. Local runoff has little effect upon salinity values at Solomons which are controlled primarily by the bay waters.

Pertinent descriptions of the area can be found in a number of publications. Salinity values in the bay were given by Wells, Bailey and Henderson (1929). A biological study of the offshore waters of the Chesapeake with general hydrographic data was published by Cowles (1930). Haight (1930) reported on the tides and currents of the bay area. Newcombe, Horne and Shepherd (1939) described studies on the physics and chemistry of the bay waters near Solomons. A discussion on the influence of the Susquehanna River on bay salinities was published by Beaven (1946). Nash (1947) gave a description of the environmental characteristics of the Patuxent River and the bay at its mouth. The general physical structure of the bay with its circulation, salinity and temperature patterns, together with discussions of factors that control circulation and mixing, has been the subject of a series of recent papers by Pritchard (1951–55).

An atlas with charts showing the seasonal salinity and temperature distribution of the bay was published by Whaley and Hopkins (1952). Periodic data reports of cruises throughout the bay and major tributaries have been issued by the Chesapeake Bay Institute (Dept. of Oceanography, The Johns Hopkins University). The Virginia Fisheries Laboratory has listed temperature observations for recent years for Gloucester Point, Virginia.

All data tabulated are from observations taken at the end of the pier of the Chesapeake Biological Laboratory at Solomons (Fig. 4). The pier extends nearly 750 feet

into the Patuxant River in a southeasterly direction. This area of the river, known as Drum Point Harbor, is of circular shape, about two miles across, lying just inside the river's entrance to the bay. Depth of water at the end of the pier is eight feet at mean low water. Rather weak tidal currents move past the pier. The main channel of the river lies about a half mile to the south, is quite broad and about 50 to 60 feet in depth. A shoal area known as Middleground lies opposite the pier along the north shore of the river with a channel 13 feet or more in depth separating it from the land. Because of this configuration, strong winds can control the direction of the current past the pier independently of the direction of tidal flow in the main channel. Usually there is a weak flow towards the southwest during flood tide and towards the northeast during ebb.

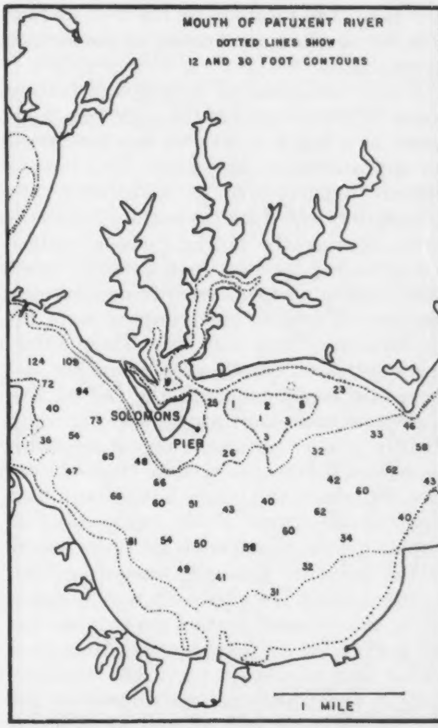

Fig. 4.—Mouth of the Patuxent River, near Solomons, Maryland, showing various depths.

Temperature Observations

All of the daily temperatures tabulated herein are the mean daily values (midnight to midnight) calculated from the charts of a thermograph with a bulb located about four feet below mean low water at the end of the pier. In order that the surface temperature may be more accurately portrayed, the thermograph is adjusted to agree with readings of a mercury thermometer immersed in a draw bucket of water taken from the upper one foot level. Whenever the thermograph is observed to vary a degree or more from the mercury thermometer, the pen arm is readjusted to bring about agreement.

The mercury thermometers used are of the type having a rated accuracy of ±0.2°C and occasional calibrations have shown an accuracy of about 0.1°. The thermograph chart can be read to within 0.2° but due to distortion of the chart paper the actual error of the chart readings may be greater than this. Prior to 1941 the temperature values were taken directly from the charts with no correction other than the re-setting of the pen arm. Since 1941 daily corrections based on daily mercury thermometer observations have been applied to the chart reading in order to eliminate pen re-setting errors and to minimize errors due to chart distortion. There have been a few instances when the thermograph clock has stopped. For those days the extremes shown on the stationary portion of the chart recording are read and temperatures for missing days supplied by interpolation when necessary. The daily means are calculated to 0.1° and it is believed that the total error of these, including mechanical error of the thermograph and reading errors, does not exceed ±0.5°C.

The daily ranges of water temperature, as shown by the thermograph charts, were tabulated for 1947, a typical year. The average daily range for the year was 1.2° with a maximum daily range of 3.0° that occurred several times in late winter and spring and again in early fall. The least daily ranges occurred during the fall and early winter when the water was overturning. It is probable that the range in the upper one foot would be greater during sum-

mer than that recorded by the bulb at four feet due to afternoon heating of the surface layer.

Weekly sampling of surface and bottom water in mid-channel of the river near Solomons, at a depth of 60 feet, was conducted for approximately three years. This showed bottom temperatures in mid-winter approximately the same as surface temperatures. During the spring months surface temperatures became increasingly higher than bottom temperatures. Maximum differences of four to eight degrees were recorded during May and June. These differences decreased rapidly in mid-summer and from late September until the end of December bottom temperatures were generally slightly above surface temperatures with occasional differences of more than one degree. Pritchard and others have shown that water temperatures, at the surface and at similar depths throughout the open waters of the bay, are generally rather uniform during most of the year with the exception of the winter months when the extreme upper portion of the bay becomes somewhat colder than the lower part. The relationships of water temperatures throughout the bay at different seasons and at different depths are well portrayed by the charts of Whaley and Hopkins (1952).

Table 1—Twenty-year Temperature and Salinity means and extremes of surface water in Patuxent River, at Solomons, Maryland.

Period	Temp. C°			Salinity ‰		
	Max.	Mean	Min.	Max.	Mean	Min.
Jan.	9.4	3.5	−.6	20.0	14.5	7.0
Feb.	8.1	3.3	−.8	19.2	14.1	7.0
Mar.	14.4	6.1	0.8	18.0	12.8	6.7
Apr.	18.3	11.5	5.6	16.9	10.8	6.0
May	24.3	18.0	11.2	15.4	10.7	6.2
June	29.6	23.5	18.8	16.3	11.0	5.4
July	31.0	26.5	21.9	16.3	12.5	7.7
Aug.	30.2	26.7	22.9	17.4	13.4	8.1
Sept.	28.0	24.0	17.8	18.4	14.7	10.8
Oct.	25.7	18.3	12.9	19.7	15.9	11.4
Nov.	18.5	12.4	6.3	19.6	16.5	11.8
Dec.	12.1	6.1	1.5	20.4	15.7	8.9
Winter		4.3			14.8	
Spring		11.9			11,4	
Summer		25.6			12.3	
Fall		18.2			15.7	
Annual		15.0			13.6	

An air-recording bulb of the pier thermograph shows that water temperatures at Solomons bear a close relation to air temperatures but exhibit a much smaller range of fluctuations. During late winter and spring, mean water temperatures lag below those of the air. In the fall and early winter water temperature means generally are above those of the air. From nearby observations made at stations across the bay there is evidence that in winter the strong prevailing westerly winds cause a drift of cold surface water to the east that is accompanied by an upwelling of warmer bottom water along the western side of the bay and in the mouth of the river at Solomons. During severe winters extensive accumulations of surface ice sometimes occur directly across the bay from Solomons while local water remains above the freezing point and ice-free. Wind caused displacements of water masses may also occur at other seasons as is evidenced in mid-summer when oxygen-poor and denser bottom water at times has been tilted up into shoaler waters along the shores of the bay near Solomons.

A summary of the 20-year monthly means and extremes of both temperature and salinity is given in Table 1.

Salinity Observations

Most of the salinity values (ppt = parts of salt per thousand) are derived from density readings taken by laboratory staff members for the records of the local tide station. These have been supplemented by values obtained from titration of daily pier samples that were taken until 1943 for other studies. The titration determinations, expressed to the nearest tenth part per mille, have been used to fill in numerous fairly long gaps that appear in the density records prior to 1943. Throughout the period there have been occasional omissions in the record over weekends and holidays when no data from either density readings or titrations were available. In order to calculate more accurately the monthly means, values have been supplied by interpolation for those days when no sample was taken.

Several periods of hourly sampling of from 24 to 48 hours duration (salinity determined by titration) have shown irregular short term variations, often to the extent of 0.2 and occasionally well over 1.0 ppt within the hour. Fluctuations corresponding to tidal cycle were slight and were masked by larger long range trends during the periods of sampling. The available hourly data are insufficient to establish the degree of fluctuation that is dependent upon tide stage. However, the presence of the observed fluctuations indicates that once-a-day samples may not always be closely representative of the prevailing salinity for a given calendar day. The limits of error of the individual salinity values presented herein are not known and vary somewhat with the observer. It is probable, however, on the basis of a number of replications, that this error (by density method) seldom exceeds ±0.5 ppt for a given reading, and that, for the 20-year average, such errors would tend to cancel out to a relatively true picture of the normal values. Also the error of individual determinations appears to be well within the range of normal 24 hour short-term fluctuations in the environment at the sampling site. Where the salinity tolerances of the biota embrace a wide range, values having a considerably less degree of accuracy than those used for oceanographic calculations may prove quite useful.

The series of weekly bottom samples from the nearby river channel at 60 feet usually showed salinity values one to two ppt higher than at the surface except during late spring and early summer when they ranged up to seven ppt higher. Occasional vertical series in the nearby bay showed a similar salinity stratification. The relation between salinities at various depths and over the entire bay at given depths is well illustrated by the published charts of the Chesapeake Bay Institute (Whaley and Hopkins 1952). Typical distribution of surface salinities in the spring and in the fall are shown by Figs. 5 and 6. Seasonal differences in volume of stream flow from the Susquehanna (contributing 49 percent of the annual fresh-water inflow to the bay), fall vertical mixing, upwellings and other mass water movements in the bay appear to constitute the major causes of salinity changes at Solomons.

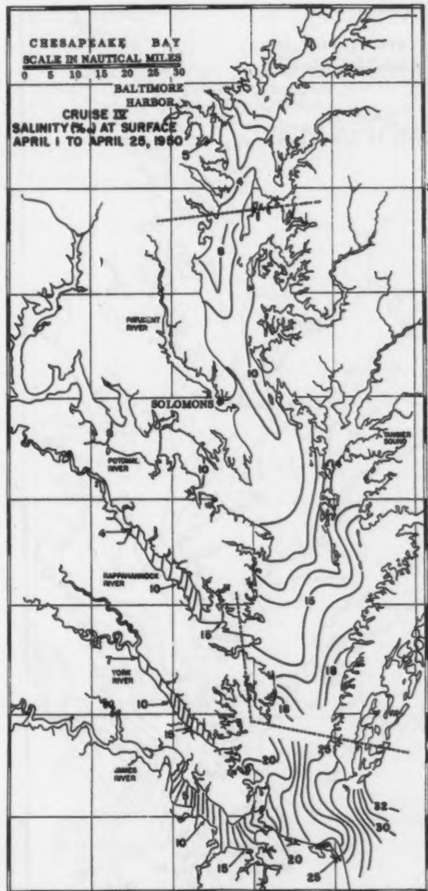

Fig. 5.—Surface salinity distribution in Chesapeake Bay, as recorded in April, 1950. After Whaley and Hopkins (1952).

Significance of the Data

The recurring cycle of water temperatures plays a major role in the time of spawning of many species, migrations within the bay, the appearance of plankton blooms, the stability and depth of water stratification, etc. The salinity pattern is more variable from year to year. Among its effects are determination of the upper limit of many seden-

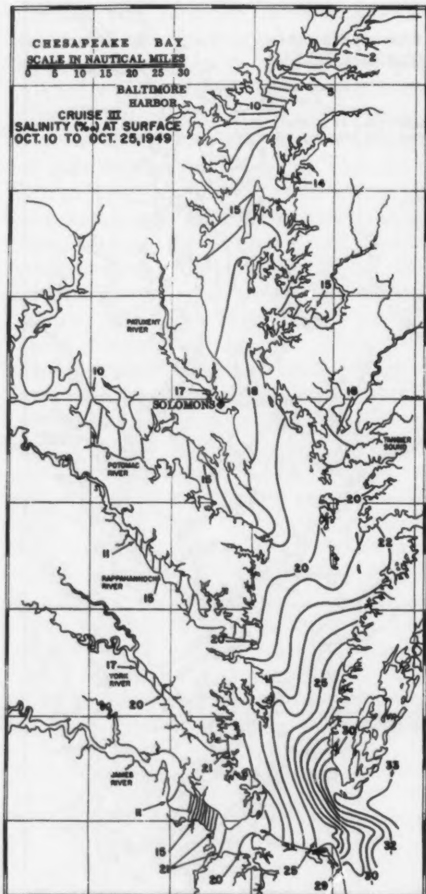

Fig. 6.—Surface salinity distribution in Chesapeake Bay, as recorded in October 1949. After Whaley and Hopkins (1952).

tary species, the extent of seasonal upstream migration by certain pelagic forms, and the ability of some fresh-water species to migrate from one tidal stream to another at the head of the bay where such migrations usually are blocked by barriers of salt water.

When temperature and salinity at Solomons are plotted against temperature and salinity readings from the tide station at Baltimore, similar trends are apparent. Numerous field readings at various stations over much of the bay also show a close relationship to surface water temperature and salinity at Solomons. The published charts of the Chesapeake Bay Institute are especially useful in showing the relationships at different points and at different depths. With them it is possible to derive from the Solomons data rough estimated values at other points for a particular period when other field data are lacking. Such estimates have shown fairly good agreement with field readings over the central portions of the bay area and general trends over the entire area agree with the trends at Solomons. Additional continuous records by this and other agencies are being gathered that will add much to our further knowledge of the dynamics of these two hydrographic features of the bay area.

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Evaluation of a Method of Reducing the Powering Requirements of Soft-Shelled Clam Dredging[1]

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ABSTRACT

The *JOHN A. RYDER*, clam dredging research vessel of the Maryland Department of Research and Education, was converted from dual-engine to single-engine powering of the pumping and propulsion systems through use of a controllable-pitch propeller designed for the specific application by Electric Boat Division of General Dynamics Corporation. The dredge pump is driven by mechanical power take-off from the propulsion engine at any desired speed, and optimal thrust is obtained by adjustment of the controllable-pitch propeller.

Tests conducted by the Department of Research and Education before and after conversion included (1) cruising speed and fuel consumption at cruising speed, (2) dredging rates, and (3) fuel requirements of dredging. Performance of the controllable-pitch propeller at cruising speed compares favorably with that of the fixed-pitch propeller formerly used. Fuel savings of about one-third are realizable with the single-engine powering system, with no sacrifice of necessary flexibility of operation.

Introduction

Operational characteristics of the Maryland soft-shelled clam dredge, mechanical shellfish digger, or escalator harvester, as the device has been called by various authors, have been described in some detail by Manning and Dunnington (1955), Manning (1957, 1959), Dickie and MacPhail (1957), and Medcof (1958, 1960). The dredge is not only capable of harvesting otherwise unavailable subtidal stocks of clams but can dig more than ten times as fast and almost twice as efficiently as a man using hand tools, thus enabling commercial exploitation of populations of relatively low density. Fuel and maintenance costs are, however, rather high.

The gear consists essentially of an inclined conveyor with a scoop at the lower (forward) end. A large centrifugal pump supplies water through a flexible hose to a transverse row of downwardly directed jet pipes mounted above and slightly forward of the leading edge of the scoop. As the jets of water loosen the bottom, propeller thrust of the boat forces the scoop ahead. Clams are elevated to the surface on the endless belt of the conveyor.

Horsepower requirements of dredging have been estimated at less than one-third of that available in the three engines used to power the boat, pump, and conveyor belt. Inasmuch as the peak efficiency of internal combustion engines does not exceed 35 percent, it is evident that reduction of the number of power sources used in dredging should result in fuel economy.

Early in 1958 the Maryland Department of Research and Education initiated a study of means of reducing the powering requirements of soft-shelled clam dredging to a single engine. It was stipulated that any method employed must reduce fuel and maintenance costs without sacrifice of flexibility of operation or uncompensated increase in capital investment.

By flexibility of operation is meant the capability of varying independently, within certain limits, propeller thrust and pump discharge. The limiting factor in speed of dredging is the rate at which the jets of water loosen the bottom ahead of the scoop. This varies with bottom structure and the velocity and volume of efflux, interrelationships of the latter two factors being fixed

[1] Contribution No. 133, Maryland Department of Research and Education, Solomons, Maryland.

in the design of a particular dredge. No available amount of propeller thrust can force the scoop through bottom which has not been loosened by the jets. Therefore, application of greater propeller thrust then is necessary to keep the scoop moving ahead through loosened bottom is wasteful expenditure of power. Experimental results indicate that excessive thrust reduces rate of dredging. Apparently, forcing the leading edges of the scoop against solid bottom interferes with the erosive action of the lateral jets. Greatly excessive thrust invariably forces the scoop out of the bottom. This apparently is due to the fact that the jets are directed somewhat backward, at an angle which is roughly the supplement of the angle of the leading edges of the scoop sides (Fig. 1). When propeller thrust reaches such magnitude that the scoop is forced against the inclined plane of solid bottom and the vertical component of thrust thus developed overcomes the weight of the dredge, the scoop rises. The commercial dredger frequently employs this phenomenon to free the dredge when forward progress is impeded, and usually with attendant breakage of clams.

Power requirements of the pump vary rather widely. For a typical dredge using a six-inch centrifugal pump, 1300 revolutions per minute (rpm) may be more than adequate where clams are very numerous in loose sand bottom. When dredging clay bottom, 1700 or more rpm may be required. Thrust requirement varies with wind and current velocity as well as the rate at which the bottom is eroded by the jets.

Of several single-engine powering systems considered, the one which offered greatest promise of meeting all of the stated criteria was based on the use of a controllable-pitch propeller which could be adjusted to provide optimal thrust over a wide range of engine speeds, with the centrifugal pump driven by mechanical power take-off from the main engine and the conveyor operated by electrical power. To simplify testing procedure and the interpretation of results, conversion of the conveyor to electrical drive has been deferred. This report concerns only the power requirements of boat propulsion and operation of the centrifugal pump, which constitute approximately 97 percent of the total power requirement of dredging.

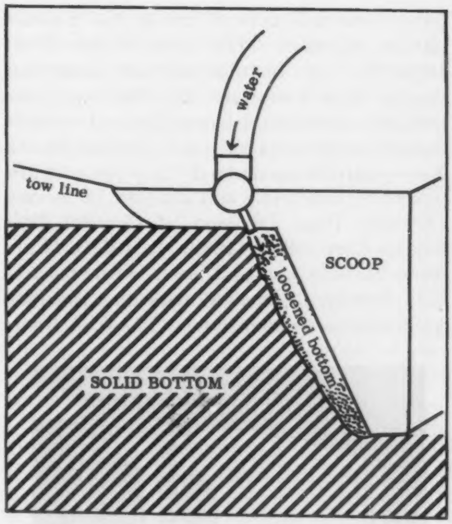

Fig. 1.—Schematic diagram of the clam dredge scoop in relation to the bottom.

Studies covered by this report became cooperative in nature when, in 1959, Electric Boat Division of General Dynamics Corporation agreed to undertake development of a controllable-pitch propeller suitable for use in the clam dredging industry. The junior author designed the propeller and controls described in the succeeding section and supervised their installation. The senior author conducted all tests, with the assistance of H. T. Pfitzenmeyer and R. P. Saunders, Maryland Department of Research and Education, and prepared this report. Fig. 3 and the accompanying description of constructional and operational features of the controllable-pitch propeller were contributed by R. D. Briggs, Jr., Head, Marine Development, Research and Development Department, Electric Boat Division of General Dynamics Corporation.

The Controllable-Pitch Propeller

Controllable-pitch propellers have been used on large vessels, such as tugs and cargo ships, for many years. More recently thev

have come into general use in the Scandinavian fisheries (*The Fish Boat*, Nov. 1958:28), but installations on American vessels have been rare. In 1957 two controllable-pitch propellers of domestic manufacture were installed on a United States Navy patrol-torpedo boat; they successfully passed service trials and are now in service (Electric Boat Division of General Dynamics Corporation, 1959). In 1958 a twin-screw installation of Liaeen-Wegner variable pitch propellers was made on a 154-foot American menhaden seiner (*The Fish Boat*, Sept. 1958:24, 25). In 1959 a controllable-pitch propeller of Danish design was installed on a 62-foot American shrimp trawler (*The Fish Boat*, Sept. 1959:26, 27).

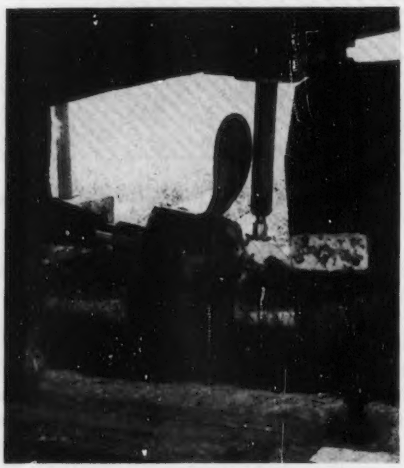

Fig. 2.—Experimental prototype of the controllable-pitch propeller installed on the *JOHN A. RYDER*.

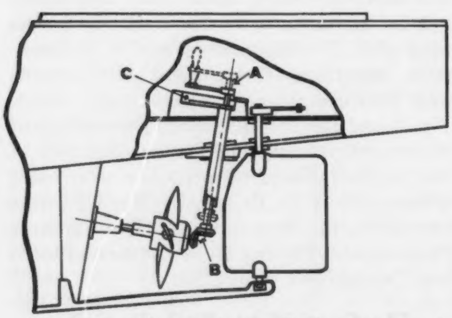

Fig. 3.—Installation of controllable-pitch propeller and controls in the *JOHN A. RYDER*. Solid lines indicate position of the actuating mechanism when pitch is being changed. (See text for identification of parts.)

With continuous-type actuation—that is, a control system which permits changing of propeller pitch without slowing or stopping the rotation of the shaft—the controllable-pitch propeller offers two major advantages over the fixed-pitch propeller: improved maneuverability and, where varying conditions of propeller loading are encountered, fuel economy. With intermittent-type actuation, which necessitates stopping the motion of the propeller shaft while the pitch of the blades is changed, the maneuverability advantage is sacrificed. Simplicity of design of the intermittent actuating mechanism, however, makes possible very substantial savings in production and installation costs. Intermittent actuation is considered adequate for clam-dredging operations, for reasons which will be discussed in a later section.

Savings in fuel realizable through use of the controllable-pitch propeller are possible because the propeller can operate at near-maximum efficiency over a wide range of conditions. Any fixed-pitch propeller is designed to deliver thrust at a certain combination of hull speed, engine power, and speed of rotation. Major change in any one of these factors seriously impairs the efficiency of the propeller. The boat engaged in the clam dredge fishery encounters extremes of propeller loading, running free when cruising to and from the fishing grounds but making headway of only about 0.1 to 0.2 miles per hour when dredging. Thus hull speed is virtually zero when dredging and propeller slip closely approaches 100 percent.

The experimental prototype propeller developed by General Dynamics Corporation is shown in Fig. 2. Design specifications included the requirements that the propeller and actuating mechanism be uncomplicated, dependable, and rugged, of modest cost and installable without extensive alterations to the boat. Fig. 3 is a diagram of the installation on the *JOHN A. RYDER*, research vessel of the Maryland Department of Re-

search and Education, which has for several years been equipped as a clam dredger. The propeller is of 19 inches diameter, with hub diameter of 5 inches and pitch range of 19 inches forward to 19 inches reverse. It was designed for 110 shaft horsepower at 1400 rpm. To maintain accurate pitch, the blades are locked into position by a non-reversing screw thread which operates a crosshead within the hub. The crosshead in turn contacts dogs located on the bases of the blades. To eliminate the sealing problem prevalent in most controllable-pitch propellers, all of the internal mechanism is constructed of non-corrosive materials, allowing the hub to be free flooding. During assembly, which is accomplished at the bench prior to installation, the hub is packed with a high pressure grease to lubricate moving parts. Once installed, no further servicing is required except an occasional application of grease through a standard pressure fitting. It should be noted that the propeller is mounted on the existing standard-taper shaft by means of an adapter, using the regular propeller nut.

To change pitch, the rotation of the propeller shaft is stopped and the crank and actuator shaft "A" are pushed down until the gears "B" engage. The crank is then rotated until the indicator pointer "C" moves to the desired pitch, and the crank is released. A spring mechanism raises the crank and actuator shaft, disengaging the gears "B". The indicator is so designed that if the crank is rotated inadvertently while the actuating mechanism is disengaged, the pointer will not move.

Testing Procedures

The vessel *JOHN A. RYDER*, of Chesapeake deadrise construction, 42 feet long over all and of 11 feet beam, was used in all testing of dual-engine and single-engine powering systems. The boat is powered by a 6-cylinder marine engine rated at 165 horsepower at 3400 rpm, with 1.5 to 1 gear reduction. Power take-off at full crankshaft speed is provided through an integral friction clutch. Before installation of the controllable-pitch propeller, the boat was equipped with a standard 3-blade propeller of 17 inches diameter and 16 inches pitch; the 6-inch-suction, 4-inch-discharge centrifugal pump was driven by a 6-cylinder automobile engine. Tests before and after conversion to single-engine powering included (1) cruising speeds, (2) fuel consumption at cruising speeds, (3) rates of dredging, and (4) fuel consumption of engines used in dredging.

Cruising speeds were determined over a measured course, averaging the times of successive runs in opposite directions.

Fuel requirements were determined by timing the consumption of 12 ounces of gasoline and averaging the results of at least three trials under each set of conditions.

Dredging rates were determined by timing 10 feet of linear progress of the dredge through firm sand bottom. At least six trials were made under each set of variables. All tests were conducted under essentially uniform conditions of wind, current, depth of water, and type of bottom dredged.

Results

Efficiency of the Controllable-Pitch Propeller at Cruising Speed

Cruising speeds and fuel consumption at cruising speeds of the *JOHN A. RYDER* with fixed-pitch and controllable-pitch propellers are shown in Fig. 4. Before conversion the boat had customarily been cruised at about 2100 rpm engine speed.

Slopes of the curves in Fig. 4 reflect differences in the complex of propeller design characteristics, discussion of which is beyond the scope of this report. It is apparent that, for the boat used in these tests, a heavily built and laden workboat, the fixed-pitch propeller of 17 inches diameter and 16 inches pitch is less efficient at cruising speed than the controllable-pitch propeller at settings of either 13 or 15 inches pitch.

Rates of Dredging with Dual-Engine and Single-Engine Powering Systems

Dredging rate with the dual-engine powering system was determined at the engine speeds which we have customarily used in dredging firm sand bottom where clams are moderately abundant. Tests of the single-engine system were conducted at engine

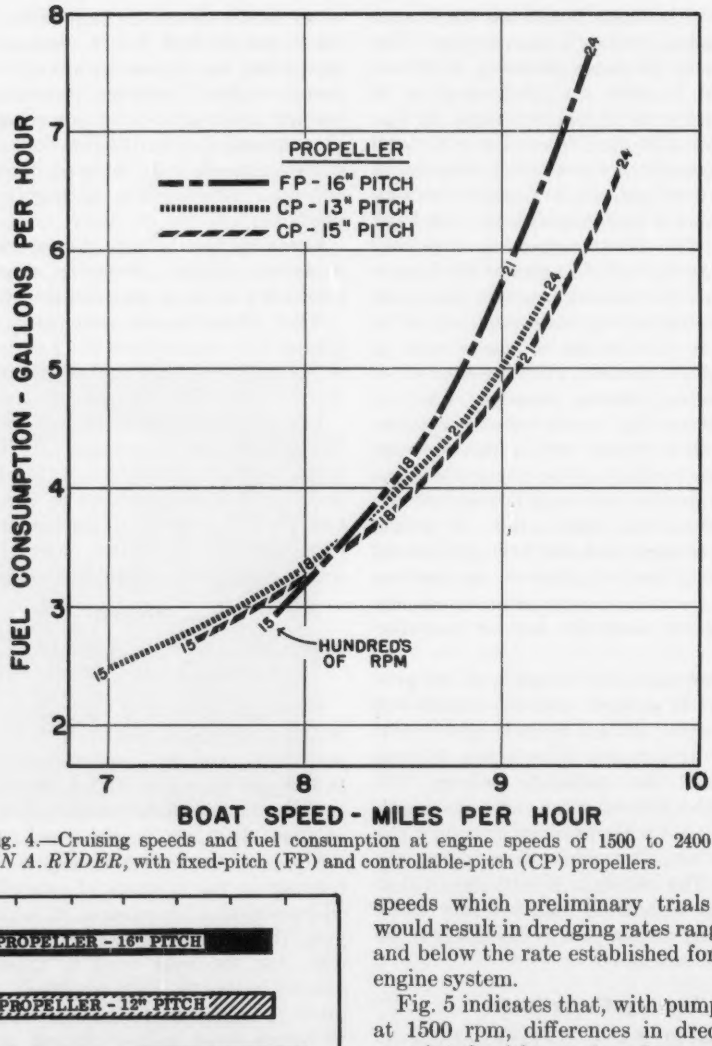

Fig. 4.—Cruising speeds and fuel consumption at engine speeds of 1500 to 2400 rpm, *JOHN A. RYDER,* with fixed-pitch (FP) and controllable-pitch (CP) propellers.

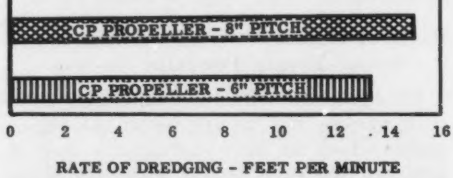

Fig. 5.—Dredging rates, dual- and single-engine powering systems, pump driven at 1500 rpm; fixed-pitch propeller at 1000 rpm, controllable-pitch propeller at 1500 rpm engine speed.

speeds which preliminary trials indicated would result in dredging rates ranging above and below the rate established for the dual-engine system.

Fig. 5 indicates that, with pump operated at 1500 rpm, differences in dredging rate associated with varying degrees of thrust are relatively small. The highest rate attained with the single-engine system exceeded that attained with the dual-engine system by 1.3 feet per minute ($p = 0.19$)[2].

[2] By p is meant the probability that the difference in means of sets of measurements is attributable to experimental error, on a scale which uses unity as the measure of absolute certainty. For example, p of 0.19 means that there are 19 chances in 100 that the difference in means may be attributed to experimental error.

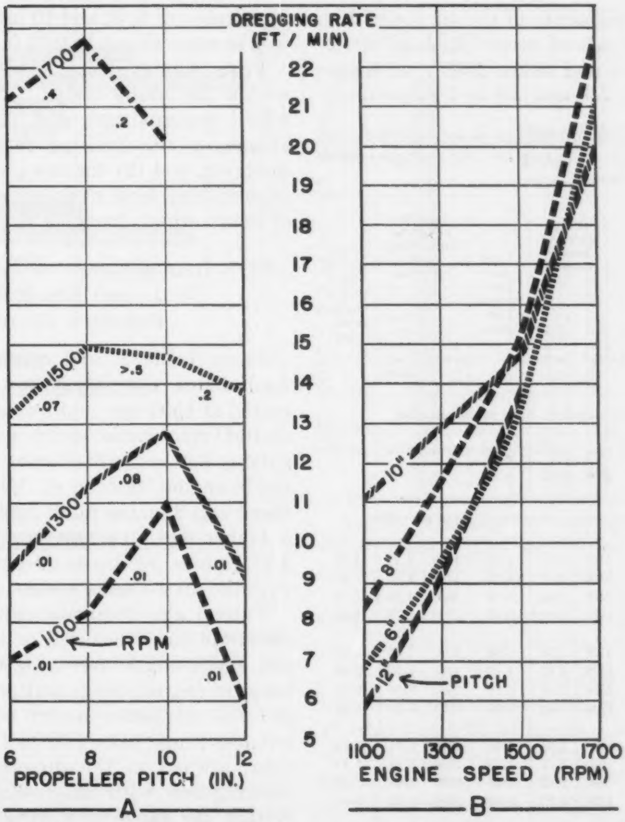

FIG. 6.—Dredging rate with single-engine powering and controllable-pitch propeller as a function of (A) propeller pitch, affecting thrust alone, and (B) engine speed, affecting both thrust and pump discharge.

Fig. 6 affords a basis for examination of dredging rate with the single-engine powering system as a function of (A) propeller pitch and (B) engine speed, and inferentially, the relative effects of pump speed and propeller thrust. No dredging rate is indicated for pitch of 12 inches and engine speed of 1700 rpm; thrust developed by this combination of pitch and speed consistently forced the dredge out of the bottom. From the data of Skene (1925), within the range of propeller speeds and pitches at which these tests were conducted, the effect on propeller thrust of a change of 1 inch in pitch is about double that of a change of 67 rpm in speed (corresponding to a change of 100 rpm in engine speed with 1.5 to 1 reduction gear). Fig. 6A shows that, at any given engine speed, increasing propeller pitch, and thus thrust, results in acceleration of dredging rate up to a certain point, beyond which the rate is retarded. The value of p for each increment (or decrement) in dredging rate is shown just below the pertinent segment of the curve.

From Fig. 6B it is apparent that, at any given pitch, an increase of 200 rpm in engine speed, resulting in increased thrust *accompanied by increased pump speed*, invariably results in acceleration of dredging rate. Only one increment—that associated with propeller pitch of 10 inches and increase of engine speed from 1100 to 1300 rpm—falls short of significance at the 95 percent confidence level, and p for that increment is 0.09. Also apparent is the steepening slope

of the upper segments of the curves of Fig. 6B. Ratios of rate of acceleration of dredging rate above and below 1500 rpm engine speed are 2.1, 2.3, and 2.8 to 1 respectively

TABLE 1.—Fuel requirements of soft-shelled clam dredging with dual-engine and single-engine powering systems.

Propeller pitch	1 engine powering propeller alone		1 engine powering pump alone		Total fuel consumed 2 engines	1 engine powering both pump and propeller		Fuel Saved by Single-engine powering
	Engine speed	Fuel consumed	Engine speed	Fuel consumed		Engine speed	Fuel consumed 1 engine	
Dual-engine system, fixed-pitch propeller								
(*in*)	*rpm*	*gal/hr*	*rpm*	*gal/hr*	*gal/hr*	*rpm*	*gal/hr*	*gal/hr*
16	1000	2.03	1500	2.42	4.45			
Single-engine system, controllable-pitch propeller[1]								
6	1100	1.83	1100	1.74	3.57	1100	2.22	1.35
6	1300	2.03	1300	2.07	4.10	1300	2.43	1.67
6	1500	2.25	1500	2.43	4.68	1500	2.96	1.72
6	1700	2.43	1700	2.84	5.32	1700	3.73	1.59
8	1100	1.86	1100	1.74	3.60	1100	2.22	1.38
8	1300	2.10	1300	2.07	4.17	1300	2.52	1.65
8	1500	2.36	1500	2.43	4.79	1500	3.15	1.64
8	1700	2.74	1700	2.84	5.58	1700	3.89	1.69
10	1100	1.89	1100	1.74	3.63	1100	2.31	1.32
10	1300	2.12	1300	2.07	4.19	1300	2.68	1.51
10	1500	2.45	1500	2.43	4.88	1500	3.40	1.48
10	1700	2.79	1700	2.84	5.63	1700	4.15	1.48
12	1100	1.99	1100	1.74	3.73	1100	2.30	1.43
12	1300	2.30	1300	2.07	4.37	1300	2.79	1.58
12	1500	2.99	1500	2.43	5.42	1500	3.47	1.95

[1] Fuel requirements of powering propeller and pump independently with the same engine were determined by mooring the boat and disengaging one or the other of the driven components. The difference in forward speed when moored as compared with that attained while dredging (0.1–0.2 miles per hour) has been determined to have a negligible effect on fuel consumption.

TABLE 2.—Rationale of differences in fuel requirements, single- and dual-engine powering in soft-shelled clam dredging.

Engine speed	Fuel consumed by engine under no load	Fuel savings, single-engine powering system (average, all pitches)
rpm	*gal/hr*	*gal/hr*
1100	1.43	1.37
1300	1.69	1.60
1500	1.83	1.70
1700	1.97	1.68

for pitches of 6, 8, and 10 inches. The value of p is approximately 0.03 in each case.

From this evidence it seems clear that, within the limits tested, (1) pump speed, which governs rate and pressure of discharge, is the limiting factor in rate of dredging, and (2) for any pump speed there is an optimal level of propeller thrust, above or below which dredging rate is retarded.

FUEL REQUIREMENTS OF DREDGING WITH DUAL- AND SINGLE-ENGINE POWERING SYSTEMS

From Table 1, fuel consumption of the dual-engine powering system with pump operated at 1500 rpm and fixed-pitch propeller at 1000 rpm engine speed is seen to be 4.45 gallons per hour. Fuel consumption of the single-engine system at 1500 rpm engine speed and 8 inches pitch setting, with which a higher dredging rate was attained, was 3.15 gallons per hour, 29 percent less than with the dual-engine system.

Table 1 also illustrates differences in fuel consumption associated with dual-engine and single-engine powering throughout the range of engine speeds and propeller pitches at which the latter system was tested. Differences range from 1.32 to 1.97 gallons per hour, always in the direction of reduced consumption with single-engine powering. Within the range of engine speeds (1500–1700 rpm) and propeller pitches (6–10 inches) with which highest dredging rates were attained, fuel savings with single-engine powering range from 26 to 37 percent.

It may be seen from Table 2 that savings in fuel effected by single-engine powering is attributable largely to the basic inefficiency of internal combustion engines. A very high percentage of the fuel consumed in driving either the pump or the propeller at any given speed is required to overcome frictional forces within the engine and operate such engine accessories as the generator and cooling system pump. The amount of fuel thus "wasted" can be approximately halved by using one instead of two power sources for dredging.

Data from Table 2 and the data for propeller pitch of 8 inches from Table 1 have

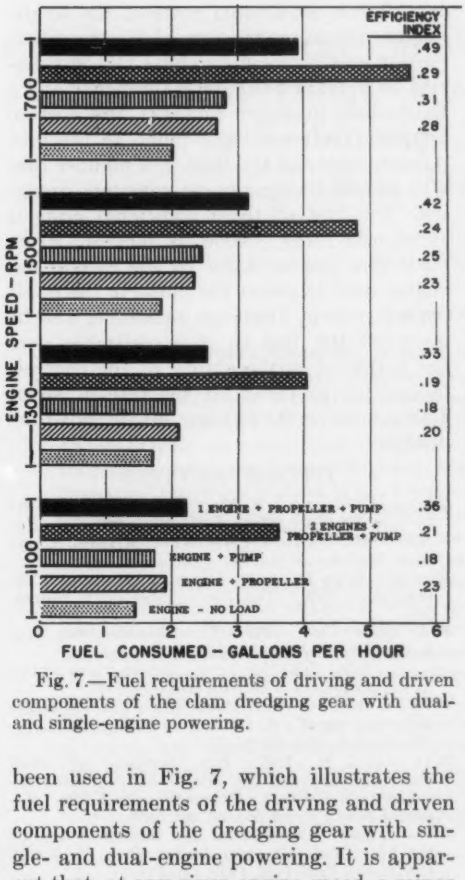

Fig. 7.—Fuel requirements of driving and driven components of the clam dredging gear with dual- and single-engine powering.

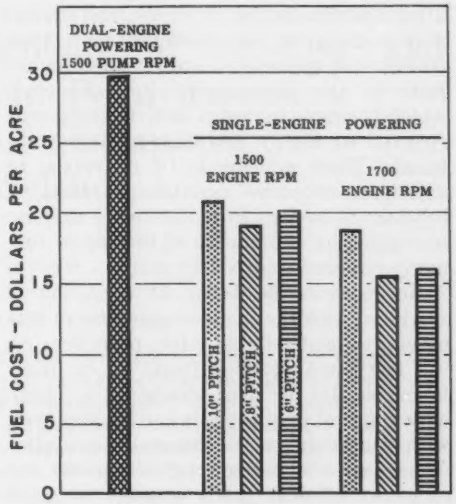

Fig. 8.—Fuel cost per acre of dredging soft-shelled clams in firm sand bottom with dual- and single-engine powering systems.

been used in Fig. 7, which illustrates the fuel requirements of the driving and driven components of the dredging gear with single- and dual-engine powering. It is apparent that, at any given engine speed, a minor fraction of the fuel used to power either the pump or the propeller is converted into useful energy. This ratio, which may be termed the "efficiency index" of the system, becomes larger as engine speed increases, as indicated in the column of decimal fractions at the right margin of the graph. This is true because fuel requirements of operating the propeller or the pump increase more rapidly with increasing engine speed than does the fuel requirement of operating the engine under no load. Greatest efficiency (0.49) is reached by driving both propeller and pump with one engine at 1700 rpm engine speed.

Areal Costs of Dredging with Dual- and Single-Engine Powering Systems

Data from the preceding two sections have been extended and combined in Fig. 8. Dredge width of 30 inches was used in converting dredging rate from linear to areal units. Fuel costs were computed on the basis of the current price of $0.31 per gallon. It will be noted that, with pump operated at 1500 rpm, single-engine powering reduces fuel costs of dredging by about one-third. At the most advantageous setting of the controllable-pitch propeller, fuel savings per unit area amount to 35 percent, and an additional 13 percent reduction accompanies an increase in engine speed from 1500 to 1700 rpm.

Discussion

In an earlier section certain criteria for an acceptable single-engine powering system were stated. It has been demonstrated that the system tested, employing a controllable-pitch propeller, meets the first of these, reduction of fuel costs, impressively.

Statistics bearing on reduction of maintenance costs associated with conversion to single-engine powering can be obtained only

after a protracted period of use, and preferably commercial use. However, more than 50 hours of operation have revealed no defects in the controllable-pitch propeller, which is simple in design and ruggedly constructed of highly corrosion-resistant materials. There appears to be no reason to anticipate excessive maintenance costs. A substantial savings in maintenance expense is realized by elimination of the engine formerly required to drive the pump.

No requisite flexibility of operation is sacrificed with the single-engine system employing a controllable-pitch propeller. At the low pitch settings found to be most favorable for efficient dredging, a fairly wide range of pump speeds can be employed with relatively small change in propeller thrust. At the tested engine speeds, the range of efficient pitch settings is great enough to meet normally varying conditions of wind and current. Pitch can be changed, without interrupting operation of the pump, in less than 30 seconds. Quantitative data are lacking, but experience indicates that single-throttle control operates to reduce breakage of clams and to smooth rate of dredging. When progress of the dredge is impeded, probable causes are (1) the presence of a solid obstruction in the path of the scoop or (2) a localized variation in bottom structure requiring greater erosive force. The commercial dredger, ordinarily having no way of knowing why progress has slowed or stopped, habitually meets the situation by temporarily increasing propeller thrust enough that the dredge rises, passing over the obstruction. Clams, and particularly the larger individuals, which burrow deep, are almost invariably broken as the dredge rises and again as it descends to normal operating level. With single-throttle control, any increase in propeller thrust is accompanied by an increase in the rate of pump discharge. Unless the obstruction is a solid object, rising of the dredge, and thus breakage of clams, is minimized.

Relative costs of outfitting a boat entering the clam fishery with single-engine or dual-engine powering system is a major factor in consideration of the fourth requirement, that single-engine powering must involve no uncompensated increase in capital investment. Additional costs of the single-engine system are the sum of (1) the difference in cost between purchase and installation of a controllable-pitch propeller and a fixed-pitch propeller and (2) the cost of coupling the centrifugal pump to the propulsion engine of the boat in a manner that will permit disengagement when not dredging. The first of these additional costs is substantial; the second is modest. From their sum can be deducted the cost of the engine used to power the pump in the dual-engine system. From the remainder can be deducted the fuel savings realizable over the period of serviceability of the controllable-pitch propeller, at the rate of about $500 a year on the average for the full-time dredger.

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Electric Boat Division of General Dynamics Corporation,
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Comparison of the Movements of Stocked and Resident Yellow Perch, *Perca flavescens*, in Tributaries of Chesapeake Bay, Maryland[1]

Romeo Mansueti

ABSTRACT

Yellow perch, *Perca flavescens*, procured from the Chester River estuary, were tagged and stocked on a "put and take" basis in the upper parts of the Severn and Magothy Rivers in tidewater Maryland. Subsequent movements were spectacularly different from those of resident fish. Stocked fish (of which about 20 percent were recaptured) attempted immediately to leave the rivers. Their essentially random movements distributed them widely, from the Susquehanna Flats to Tilghman Island in Chesapeake Bay, over a salinity range from tidal freshwater to about 12 ppt. Recaptures of about 10 percent of tagged resident fish indicate that few of them leave the Severn River.

Most of the recaptures of stocked fish were taken by commercial netters outside the two rivers of stocking (53 and 82 percent from the Severn and Magothy, respectively). Anglers in the rivers and in Chesapeake Bay accounted for the balance. A small, unknown number of stocked fish remained within the Severn and Magothy Rivers for over two years and were presumably acclimatized. Tag recaptures were also returned from Chesapeake Bay localities for a two year period following the February 1956 stocking. Most (75 percent) of the tagged fish were recovered outside the two tributaries during the first four months; many were taken during the first month of freedom. Very few stocked fish returned to the Chester River. It is suggested that those trying to return failed because they were removed too far to rely on their visual, tactile and olfactory faculties to guide them successfully. A discussion of the other factors that might bring about the striking dispersal is also given. It is concluded that "put and take" stocking of adult estuarine yellow perch in strange waters is of doubtful management value in Chesapeake Bay.

Introduction

Very little information is available on the movements and behavior of adult fish stocked in estuaries and other marine habitats. This is due largely to the lack in tidewater areas of this type of management, which is widespread in inland freshwaters. The opportunity to contribute knowledge to the effects of planting adult fish from one locality into another area in tidewater occurred in late winter of 1955–56. At that time two sport fishing organizations had made arrangements for the capture of adult, pre-spawning yellow perch, *Perca flavescens* (Mitchill) in the upper tidal reaches of the Chester River on the Eastern Shore, for stocking in the Severn and Magothy Rivers, both on the western shore of Maryland.

The Chester River is the second largest tributary of the Chesapeake Bay on the east, being surpassed in size only by the Choptank. The water is normally brackish within the river where the salinity ranges from 2 to 6 ppt, but following heavy freshets, it may become almost fresh. Across the bay, the Severn and Magothy Rivers are relatively small tributaries of western Chesapeake Bay and are characterized by sharp gradients of salinity. The latter varies seasonally in different parts of the estuaries but ranges from tidal fresh at the head to about 10 ppt at the mouth. The Chester River produces large commercial catches of estuarine fishes, including yellow perch. Fishing in the Severn and Magothy

[1] Contribution No. 134, Maryland Department of Research and Education, Solomons, Maryland.

is restricted to anglers. Yellow perch are important species in the creel of most anglers in the brackish streams, hence the support for the "put and take" stocking experiment. Local organizations also hoped that these fish would effectively augment the local stocks.

These objectives were set up: (1) to obtain information on the yield to anglers which might be expected from the "put and take" stocking of adult yellow perch; (2) to compare movements of resident fish with those of transplanted or displaced adult fish from the area that already supported the resident population; (3) to obtain information on the vital statistics of stocked fish in order to compare those that were recaptured in the tributaries with those taken in Chesapeake Bay; and (4) to determine if a particular segment of the tagged fish is vulnerable to fishing.

Acknowledgments

Dr. L. Eugene Cronin, Director of the Maryland Department of Research and Education, recognized the special importance of the tagging study and provided impetus to the project. Mr. Earl Walker, former Biologist at the Chesapeake Biological Laboratory, now with the U. S. Fish and Wildlife Service, and Mr. Edgar Hollis, Fish and Crab Culturist with the Maryland Department of Tidewater Fisheries, generally coordinated the work by seeing that commercial fishermen were contacted and that personnel were available from various state departments during field operations. Mr. Edwin Barry, Chief of Fish Management, Maryland Game and Inland Fish Commission, provided some personnel and tank trucks for live transfer of the fish. Many biologists from the Chesapeake Biological Laboratory and a number from participating agencies processed and tagged the fish with the author, and their aid is gratefully acknowledged.

Methods and Materials

Resident Fish

Resident yellow perch were seined, trapped and tagged during March of 1954 (323 fish) and 1955 (342) by Earl Walker and the author on the spawning area of Severn Run above the intersection of U. S. Route 301. Red Petersen plastic disks, with the Chesapeake Biological Laboratory name and address, and the appropriate message of a reward, were affixed with stainless steel pins beneath and between the two dorsal fins above the vertebral column line. A reward of 50¢ per tag was sent to fishermen returning them with complete recapture data on date, locality, gear and other pertinent information related to recovery. Data on length, weight, sex and scale samples were taken on all fish. Size distribution, mean lengths and numbers of these tagged fish, largely males, are shown in Fig. 1. Tag returns are minimal since no extensive effort was made to canvass fishermen in the field for tags. Additional information on later tagging has been derived from Muncy (1958B:21, 24, and 1959:11), who conducted an intensive study of the yellow perch of the Severn.

Stocked Fish

Stocked yellow perch were tagged in the same manner as the resident fish. They were procured from Captain John C. Edwards, a licensed commercial fisherman of Rock Hall, Maryland, by the Maryland Game and Inland Fish Commission and moved with the aid of a tank truck, a driver and one helper. Personnel from the Maryland Tidewater Fisheries cooperated. All the fish were caught with fyke nets in the northeast fork of Langford Bay, a tributary of the Chester River. They were held in live boxes several days before being transported and stocked.

Approximately half of the stocked fish in each of the tributaries were tagged. All fish were in good condition when released. Table 1 gives a summary of the numbers, locations, and dates of stocking of the released fish. Data on length, weight, and sex were collected from 995 and 1038 tagged yellow perch, of which scales for age and growth were collected from 446 and 575 fish stocked in the Severn and Magothy, respectively. Many of the males were in spawning condi-

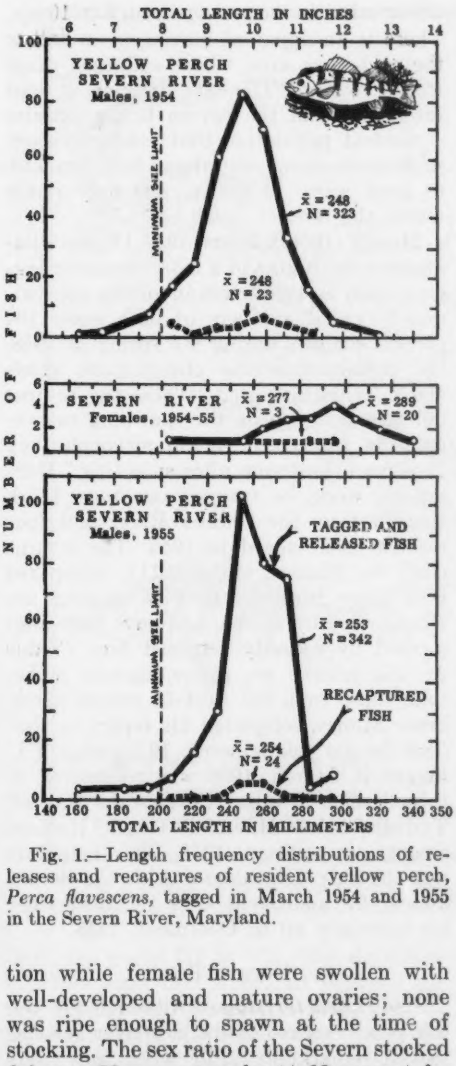

Fig. 1.—Length frequency distributions of releases and recaptures of resident yellow perch, *Perca flavescens*, tagged in March 1954 and 1955 in the Severn River, Maryland.

tion while female fish were swollen with well-developed and mature ovaries; none was ripe enough to spawn at the time of stocking. The sex ratio of the Severn stocked fish was 38 percent males to 62 percent females, while those in the Magothy were 37 males and 63 females. Most of the fish (72 percent) were between 200 and 230 mm total length (8 to 9 inches) in the two rivers. In the Severn 16 percent ranged from 230 to over 280 mm (9 to 11 inches) and 13 percent were slightly below 200 mm. In the Magothy 20 percent ranged from 230 to 300 mm (9 to 12 inches) and 8 percent were slightly below 200 mm (Fig. 3).

Table 1.—Summary of numbers and localities of introduction of yellow perch, *Perca flavescens*, originally from the Chester River, and stocked in the Severn and Magothy Rivers in February, 1956.

No. Fish	Date	Pounds	Area	Disposition
			Severn River	
995	2-8-56	301	Indian Landing	Tagged and released
934	2-14-56	300	Indian Landing	Released
1929		601		
			Magothy River	
368	2-16-56	116	Cypress Creek	Tagged and released
883	2-21-56	280	Cypress Creek	670 tagged and released; 213 released
1150	2-23-56	351	Throughout system	Released
2401		747		

Results and Discussion

Resident Fish

Movements:—Extensive data are available on the movements of yellow perch resident in the Severn River. Table 2 compares the tagging returns from 1954 and 1955 releases by season with 1958 tagging returns by Muncy (1958B:21 and 1959:11). Fig. 1 shows the length frequency distribution and mean sizes of all releases and recaptures of fish tagged in 1954 and 1955. Virtually the entire sample consisted of males, since the latter were the most available during the tagging operations on the former site of the yellow perch hatchery. Great efforts were expended during the spawning run to obtain females by means of seines, fyke nets and gill nets, but with little success. Muncy (1958B:24) suggested that males remained on the spawning grounds or returned several times while females left the area immediately after spawning. He recaptured some males as many as three times during the spawning period while females were recaptured much less frequently. In general the males tagged in 1954–55 were somewhat larger, on the average, than those

TABLE 2.—Seasonal comparison of the number of resident yellow perch, *Perca flavescens*, recaptured in the Severn River, after being tagged in March 1954, 1955, and 1958.[1]

Season[2] and days out	Year of Tagging					
	1954		1955		1958[3]	
	Number	Percent	Number	Percent	Number	Percent
Spring (0–90)	12	52.2	3	9.7	21	12.6
Summer (91–180)	3	13.0	8	25.8	45	27.2
Autumn (181–270)	3	13.0	8	25.8	70	42.2
Winter (271–360)	1	4.4	—	—	2	1.2
Spring (361–450)	1	4.4	1	3.2	10	6.0
Summer (451–540)	—	—	2	6.4	4	2.4
Autumn (541–630)	3	13.0	2	6.4	14	8.4
Winter (631–720)	—	—	1	3.2	—	—
Spring (721–810)	—	—	—	—	—	—
Summer (811–900)	—	—	1	3.2	—	—
Autumn (901–990)	—	—	1	3.2	—	—
Winter (991–1080)	—	—	—	—	—	—
Spring (1081–1170)	—	—	4	12.9	—	—
Total recaptured	23	100.0	31	100.0	166	100.0
Total tagged & released, & percent recaptured.	323	7.1	359	8.6	1281	12.9

[1] One specimen tagged in 1955 was recovered in the Magothy River by an angler, while another tagged in 1958 was recaptured on the Susquehanna Flats in upper Chesapeake Bay.

[2] Spring (March, April and May), . . . and Winter (December, January and February).

[3] Summarized from Muncy (1958B:21) and augmented by tag recaptures subsequently received.

stocked from the Chester River. The former also compares favorably with the distribution of males given by Muncy (1959:11). The few females averaged somewhat larger than those stocked from the Chester River (Fig. 3).

All marked resident fish within the Severn were recaptured therein with the exception of three specimens at the junction of the river and Chesapeake Bay, and one from near the entrance of the Magothy River. Of all the returns, 83 and 61 percent of the tagged fish for 1954 and 1955, respectively, were recaptured during the first year. They averaged 7.7 (range of 0.5 to 15) and 7.3 miles (range of 0.5 to 20) during each of the respective years, all within the river. In 1955, the specimen found in the Magothy River had traveled the distance of 20 miles. The pattern of movement is downstream from the spawning area (Fig. 2) after mid-April. During summer there is a widespread dispersal throughout the river to the mouth where salinities may range from 6 to 10 ppt. There is an apparent movement in fall to the mid-river area where salinities range from 4 to 8 ppt. The data suggests, at least for males, that the Severn River contains a resident population that conducts short, semi-anadromous migrations from brackish to fresh water to spawn, and only rarely leaves the river.

Muncy (1958B:24 and 1959:11) has summarized the results of a more extensive tagging study in the Severn involving approximately equal numbers of both sexes (54 percent males), during the spring of 1958. He corroborates the observations made above, remarking that "These tag returns indicate that fish on the spawning run remain in this river system although they disperse downstream after spawning." During his work, he trapped two tagged fish stocked from the Chester River and four resident fish tagged in 1955. The returns cited in Muncy (1958B:211), compared with those from the 1954–55 tagging, are summarized by season, and have been augmented by recently returned tags (Table 2). His returns are percentagewise higher than those from the 1954–55 yellow perch. Since Muncy completed his report, a resident female yellow perch, 12.2 inches T.L. tagged in March, 1958 was recaptured in a haul seine in upper Chesapeake Bay off Tydings, below Havre de Grace, Harford County, in autumn, 1958. This recapture was the only fish taken outside the Severn among 27 additional tags returned since his summary up to December, 1958.

STOCKED FISH

Size characteristics:—Although the yellow perch stocked in the two river systems looked remarkably alike when they were being tagged, analysis of differences in the means of total length of the two sexes by water shows some apparently significant differences. Fig. 3 illustrates the great differences between sexes; i.e., males were consistently smaller than females, a condition that was expected. Muncy (1958A:12) studied scale samples of stocked fish from the Chester River for age composition of the two sexes and found that they ranged

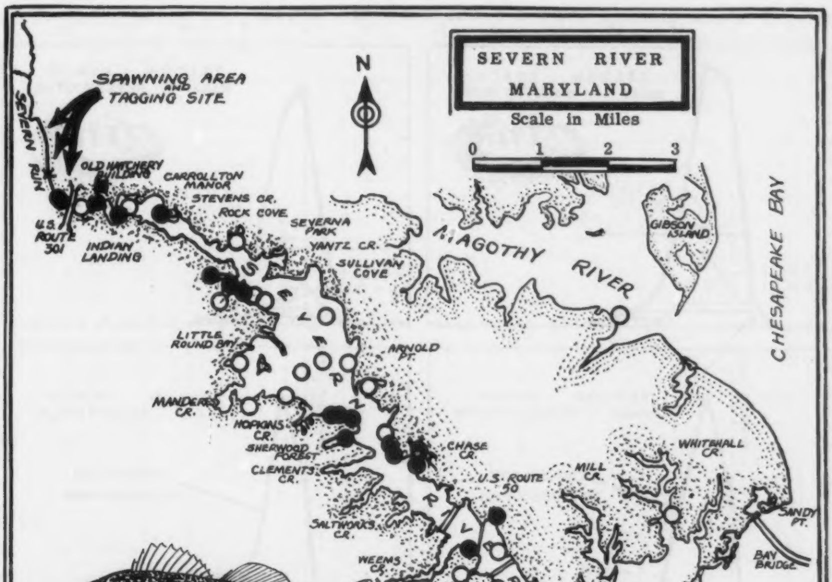

Fig. 2.—Map of the Severn River showing recapture localities of resident yellow perch, *Perca flavescens,* tagged in March 1954 and 1955 and recovered by anglers up through 1958.

from age group III to VII. The difference in mean sizes that appeared between the two rivers was unexpected, since all the fish came from the same source. A t-test of the significance of the difference between the mean sizes for both sexes between the Severn and Magothy indicated that they were statistically high ($p > 0.01$), which can be seen in the graphic comparison of means in Fig. 3. It also shows that the size differences between males is 1.5 mm and between females is 3.2 mm, both of very small magnitude for this species. It should be stressed that there is no apparent practical difference in these means (see Simpson, et al, 1950:173, for a succinct discussion of this problem of statistical evaluation). Since both males and females stocked in the Severn were slightly smaller than the two sexes in the Magothy, it is possible that the stocked fish in the two rivers could have come from slightly different populations separated by time and space in the Chester River. Table 1 indicates that early-caught fish were stocked in the Severn, while those caught later in February were placed in the Magothy. There is some unpublished evidence that early running fish, especially white perch, in Chesapeake Bay and tributaries consist of the smaller and younger

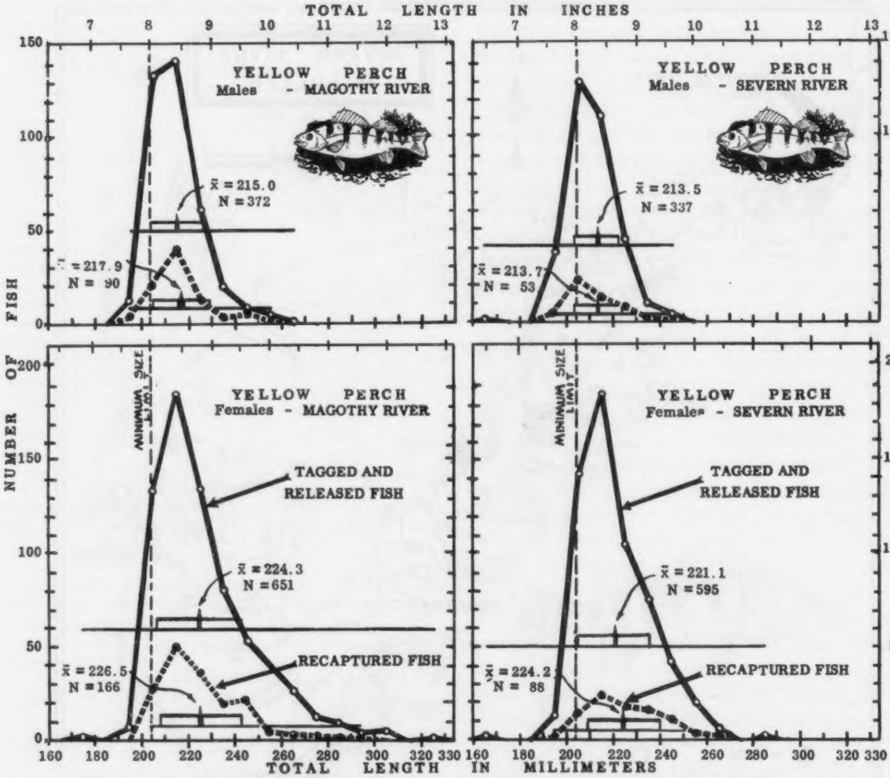

Fig. 3.—Length frequency distributions and mean total lengths of releases and recaptures of displaced yellow perch, *Perca flavescens*, stocked in the Magothy and Severn Rivers in February, 1956 from the Chester River. The graphical inlay of mean lengths consists of the following: horizontal base line = range of variation; vertical point = mean; blackened part of each bar = two standard errors of the mean on either side of the mean; white bar plus one half of blackened bar = one standard deviation on either side of the mean. Considerable reliance can be placed on the significance of the difference between samples if the corresponding black bars are separated or only slightly overlap.

individuals in a population, hence a possible explanation of the small differences in average sizes of stocked yellow perch. The mean size of 56 yellow perch of unknown sex, some of which may have been immature, was 210.7 mm. These, which were stocked in the Severn, were significantly smaller than the males from either river.

Released versus recaptured fish:—Fig. 3 shows the length distribution and mean sizes, at stocking, of recaptured yellow perch with the tagged and released sample. Although the differences in the sizes are statistically significant between these two groups of fish, except for males in the Severn River, these differences are also of such a small magnitude that they are of no practical importance. In general it can be assumed that the recaptured fish of each sex and from each river system was a random sample of tagged and released fish. Thus there is no reason to believe that a special segment was vulnerable to fishing. About 10 percent of all the fish released were below the minimum legal limit of eight inches, and it appears that the recaptures maintained this same percentage.

TABLE 3.—Recaptures of "put and take" stocked yellow perch, *Perca flavescens*, during monthly periods by anglers and netters within the Severn and Magothy Rivers and in Chesapeake Bay.

Year		Tagged and Stocked in Severn River, N = 995										Tagged and Stocked in Magothy River, N = 1038									
		Sportsmen						Netters		Grand Total		Sportsmen						Netters		Grand Total	
Season	Days Free	Inside River		Outside River		Total		Outside River				Inside River		Outside River		Total		Outside River			
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Spring 1956	1–30	9	5.5	2	1.2	11	6.6	29	17.6	40	24.2	5	1.9	6	2.3	11	4.2	120	45.9	131	50.1
	31–60	1	0.6	4	2.4	5	3.0	28	16.9	33	20.0	—	—	2	0.8	2	0.8	71	27.2	73	28.0
	61–90	1	0.6	1	0.6	2	1.2	3	1.8	5	3.0	3	1.1	2	0.8	5	1.9	6	2.3	11	4.2
	91–120	2	1.2	1	0.6	3	1.8	1	0.6	4	2.4	4	1.5	—	—	4	1.5	5	1.9	9	3.4
	Total	13	7.9	8	4.8	21	12.7	61	37.0	82	49.8	12	4.6	10	3.8	22	8.4	202	77.5	224	85.9
Summer 1956	121–150	2	1.2	2	1.2	4	2.4	1	0.6	5	3.0	4	1.5	—	—	4	1.5	1	0.4	5	1.9
	151–180	8	4.8	1	0.6	9	5.5	—	—	9	5.5	—	—	—	—	—	—	—	—	—	—
	181–210	5	3.0	1	0.6	6	3.6	—	—	6	3.6	3	1.1	—	—	3	1.1	—	—	3	1.1
	Total	15	9.1	4	2.4	19	11.5	1	0.6	20	12.1	7	2.7	—	—	7	2.7	1	0.3	8	3.1
Fall 1956	211–240	3	1.8	—	—	3	1.8	—	—	3	1.8	2	0.8	—	—	2	0.8	—	—	2	0.8
	241–270	14	8.5	—	—	14	8.5	—	—	14	8.5	8	3.1	—	—	8	3.1	—	—	8	3.1
	271–300	3	1.8	—	—	3	1.8	—	—	3	1.8	—	—	—	—	—	—	—	—	—	—
	Total	20	12.1	—	—	20	12.1	—	—	20	12.1	10	3.8	—	—	10	3.8	—	—	10	3.8
Winter 1956	301–330	3	1.8	1	0.6	4	2.4	—	—	4	2.4	—	—	1	0.4	1	0.4	—	—	1	0.4
	31–360	1	0.6	—	—	1	0.6	—	—	1	0.6	—	—	2	0.8	2	0.8	—	—	2	0.8
	361–390	—	—	—	—	—	—	1	0.6	1	0.6	—	—	—	—	—	—	2	0.8	2	0.8
	Total	4	2.4	1	0.6	5	3.0	1	0.6	6	3.6	—	—	3	1.1	3	1.1	2	0.8	5	1.9
First Year	Total	52	31.5	13	7.8	65	39.4	63	38.2	128	77.6	29	11.1	13	4.9	42	16.1	205	78.5	247	94.6
Spring 1957	391–420	—	—	1	0.6	1	0.6	13	7.9	14	8.5	—	—	—	—	—	—	—	—	—	—
	421–450	—	—	—	—	—	—	2	1.2	2	1.2	—	—	—	—	—	—	2	0.8	2	0.8
	451–480	3	1.8	2	1.2	5	3.0	2	11.2	7	4.2	2	0.8	—	—	2	0.8	2	0.8	4	1.5
	Total	3	1.8	3	1.8	6	3.6	17	10.3	23	13.9	2	0.8	—	—	2	0.8	4	1.5	6	2.3
Summer 1957	481–510	1	0.6	—	—	1	0.6	—	—	1	0.6	1	0.4	—	—	1	0.4	1	0.4	2	0.8
	511–540	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	541–570	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Total	1	0.6	—	—	1	0.6	—	—	1	0.6	1	0.4	—	—	1	0.4	1	0.4	2	0.8
Fall 1957	571–600	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	601–630	3	1.8	—	—	3	1.8	—	—	3	1.8	1	0.4	—	—	1	0.4	—	—	1	0.4
	631–660	1	0.6	—	—	1	0.6	—	—	1	0.6	—	—	—	—	—	—	—	—	—	—
	Total	4	4.8	—	—	4	2.4	—	—	4	2.4	1	0.4	—	—	1	0.4	—	—	1	0.4
Winter 1957	661–690	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	691–720	—	—	—	—	—	—	3	1.8	3	1.8	—	—	—	—	—	—	5	1.9	5	1.9
	721–750	—	—	—	—	—	—	2	1.2	2	1.2	—	—	—	—	—	—	—	—	—	—
	Total	—	—	—	—	—	—	5	3.0	5	3.0	—	—	—	—	—	—	5	1.9	5	1.9
Second Year	Total	8	4.8	3	1.8	11	6.6	22	13.3	33	20.0	4	1.5	—	—	4	1.5	10	3.8	14	5.1
Spring 1958[1]	751–780	—	—	—	—	—	—	2	1.2	2	1.2	—	—	—	—	—	—	—	—	—	—
	781–810	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	811–840	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Total	—	—	—	—	—	—	2	1.2	2	1.2	—	—	—	—	—	—	—	—	—	—
Summer 1958	841–870	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	871–900	2	1.2	—	—	2	1.2	—	—	2	1.2	—	—	—	—	—	—	—	—	—	—
	Total	2	1.2	—	—	2	1.2	—	—	2	1.2	—	—	—	—	—	—	—	—	—	—
Third Year	Total	2	1.2	—	—	2	1.2	2	1.2	4	2.4	—	—	—	—	—	—	—	—	—	—
1956–1958	Grand Total	62	37.6	16	9.8	78	47.3	87	52.7	165	100.0	33	12.6	13	5.0	46	17.6	215	82.4	261	100.0

[1] Muncy (1959: 11) reported that two tagged fish stocked from the Chester River into the Severn in February, 1956, were gillnetted in spring 1958 during biological studies on the spawning area in the Severn River.

General nature of recaptures:—Early results of the tagging were summarized by Walker (1956:1–8), Mansueti and Murphy (1956:3, 6), and Mansueti, Murphy and Walker (1957:1–3). Since then additional data have been analyzed. Table 3 summarizes the tag returns by monthly periods and general areas of recaptures in relation to the river of stocking. The netting of tagged yellow perch took place largely in the spring months outside both rivers. Commercial fishing is illegal in both rivers. Angling returns, which were concentrated within the two river systems, seem to be spread evenly over spring, summer, and fall with a drop-off in winter. As of spring 1960, 165 yellow perch (16.6 percent) from the Severn River stocking, while 261 fish (25.1 percent) from the Magothy River stocking, had been recaptured by all fishermen. The differences between these totals and those given in Fig. 3 are due entirely to fish of unknown sex which were in a great minority in both rivers.

Of the recaptures from the releases in the Severn River, anglers took 37 percent within and 10 percent outside the river, while the balance of 53 percent were taken outside the river by netters in various parts of Chesapeake Bay (Fig. 4). Among the recaptures from the Magothy River releases, anglers took 13 percent within and 5 percent outside the river, while the balance of 82 percent were taken outside the estuary by netters (Fig. 5). Overall, anglers accounted for more catches within the rivers than outside in Chesapeake Bay. A small number of tag returns have originated in the two rivers during 1957, but a two-fold number of returns have originated in Chesapeake Bay at the same time. In 1958, the returns from the Severn releases were very small and were equally divided between river and bay (Table 3).

Table 2 shows that tag returns of resident fish were generally low in spring, increased during the summer, reached a high in fall, and slumped in the winter months. The pattern of angling returns of stocked fish by seasons in the Magothy and Severn differs in that there are less marked variations in catches between the seasons from spring to fall (Table 3). Creel census data in the Magothy River during 1957 (Elser, 1958: Fig. 1–2) revealed a maximum fishing pressure during the summer months, although the yellow perch catch was highest in May. Thus the anglers' catch of yellow perch may not be related directly to heavy fishing pressure but rather to the seasons in which yellow perch bite best. In general, the angling harvest of stocked and resident yellow perch is relatively low. Only 7 and 4 percent of all tagged stocked fish in the Magothy and Severn were taken by hook and line, respectively. Muncy (1958:24) shows that even with a resident population, which are not exploited by netters, hook and line returns amounted to 10.3 percent of 1217 tagged fish about legal-sized and over (8.0 inches total length).

Pattern of movement:—The pattern of movement in time in both rivers suggests that many of the stocked yellow perch headed downstream, entered the Chesapeake Bay and dispersed. Most of the returns have been from areas located at the mouths of the Severn and Magothy Rivers in Anne Arundel County and from off Baltimore and Kent Counties in Chesapeake Bay (Fig. 4 and 5). Since tag returns reflect the location of fishing effort, and not necessarily where the majority of the fish are located, it is important to accept the returns with these reservations. Commercial fishing by stake gill nets is relatively intensive during the spring months in the area of high density recaptures. Tag returns, however, have also been sent in by fishermen from Bush River to Taylor's Island and from the Chester, Choptank, Gunpowder, Rhode and South Rivers. Few tags were returned from within the Severn and Magothy Rivers in the period immediately following the tagging, but a small, though steady, number were returned from these estuaries during summer and fall. Thus, a small, but unknown, number remained within the Severn and Magothy for over two years (Table 3).

Some differences in the degree of dispersal of fish from the two rivers was evident. The Magothy returns indicated that a large proportion of the stocked fish started out of the river very quickly and scattered through the central part of the Chesapeake Bay.

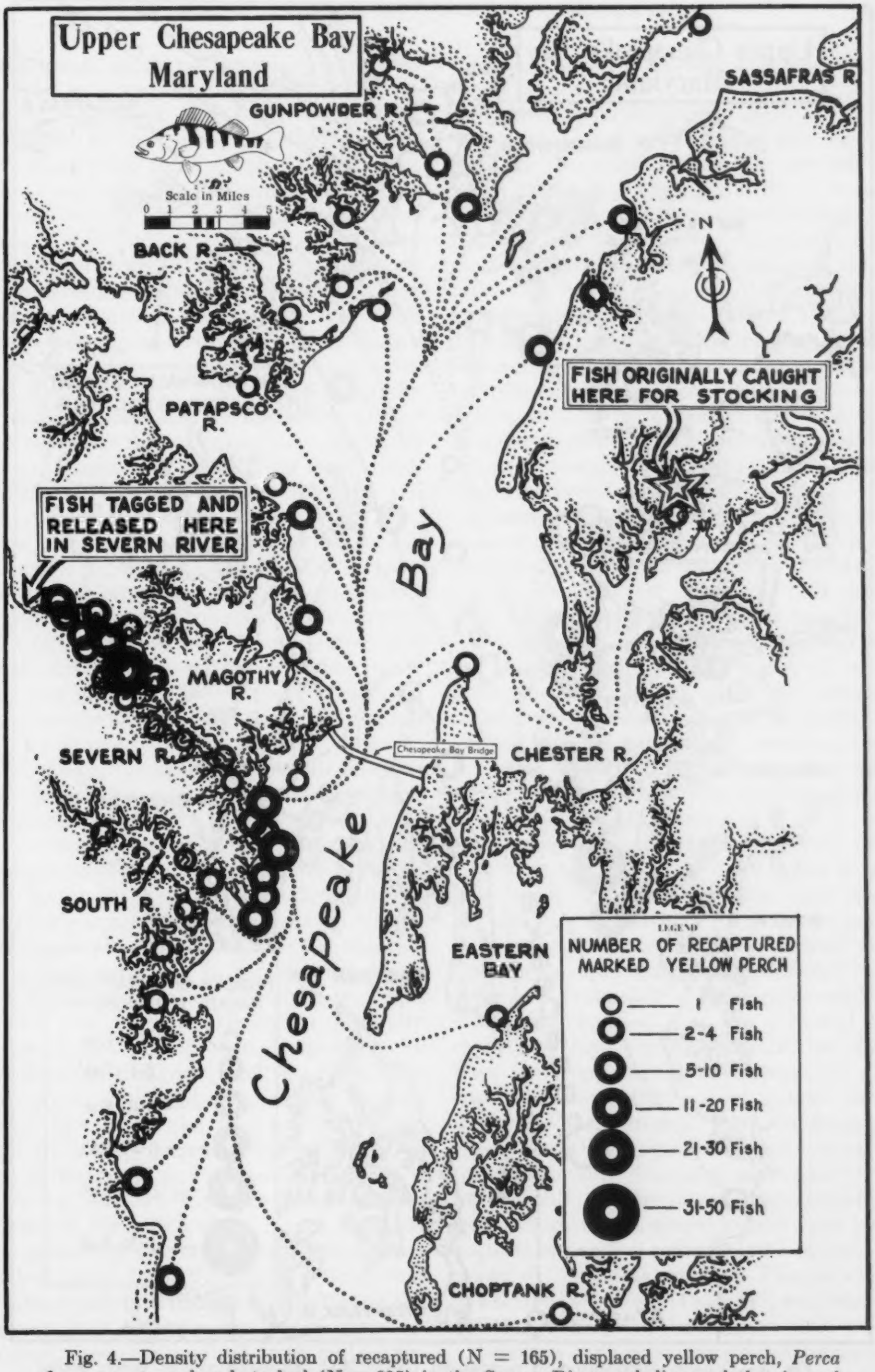

Fig. 4.—Density distribution of recaptured (N = 165), displaced yellow perch, *Perca flavescens*, tagged and stocked (N = 995) in the Severn River and dispersed therein and in various parts of upper Chesapeake Bay, Maryland.

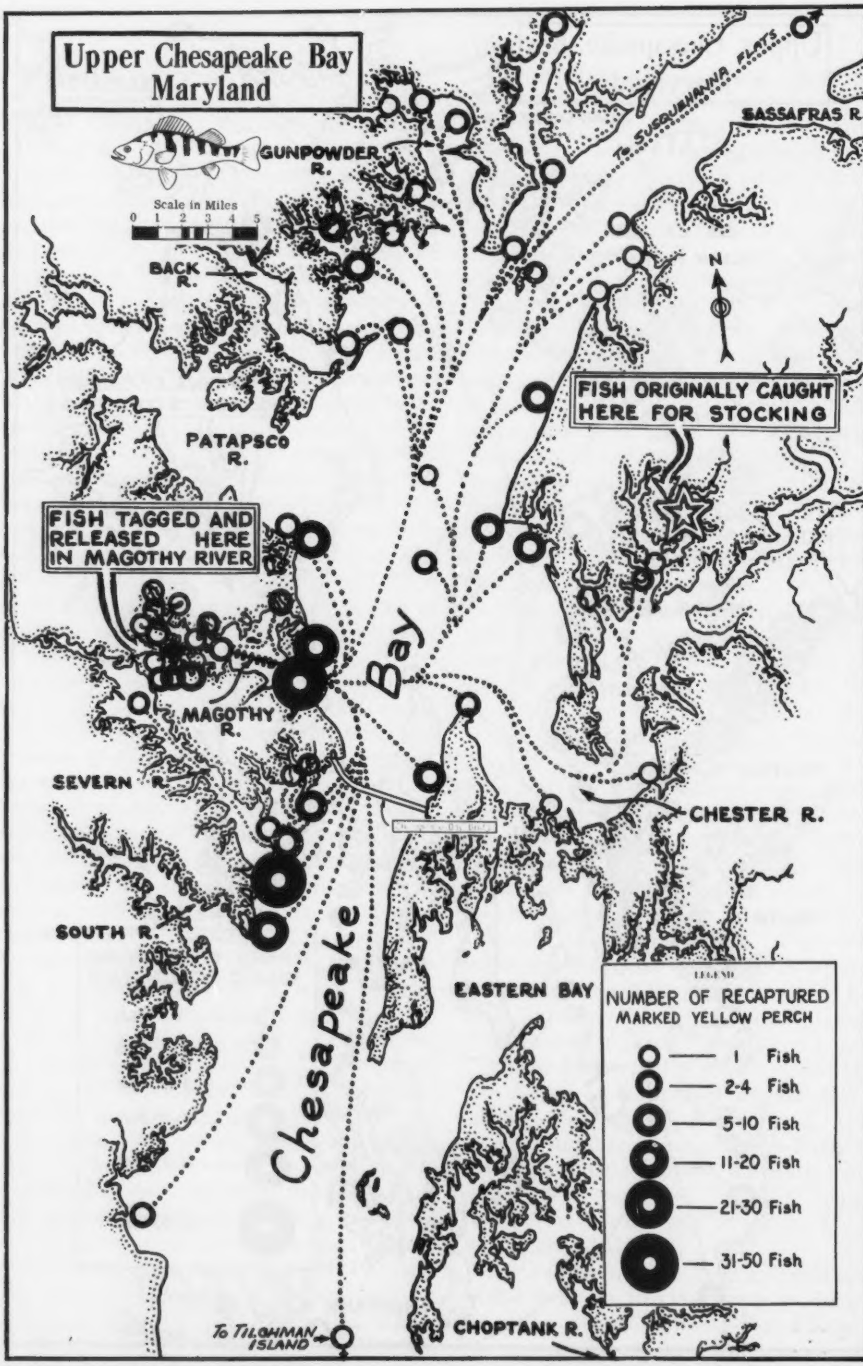

Fig. 5.—Density distribution of recaptured (N = 261), displaced yellow perch, *Perca flavescens,* tagged and stocked (N = 1038) in the Magothy River and dispersed therein and in various parts of upper Chesapeake Bay, Maryland.

Such scattering is not unusual among fish stocked in a strange environment; for example, Carlander and Ridenhour (1955: 188–9) found that young-of-the-year northern pike spread to all parts of Clear Lake, Iowa, even when stocked at one end. Severn returns, on the other hand, indicated that stocked fish did not leave in such large numbers, although those that left spread almost as widely as those from the Magothy (Fig. 4 and 5). Generally, the Severn River group was tagged and stocked far upstream almost on the known spawning area (Muncy, 1959:2–3), while the Magothy River group was stocked somewhat further downstream. Both groups were displaced over a distance of roughly 25 to 30 miles from the river of origin. Aside from the slight size differences between the two groups of stocked fish discussed earlier and shown in Fig. 3, there are no other discernible factors other than geography that might account for the differences in the number that left the two rivers. The size differences might contribute to an understanding of the different migratory behavior if it is assumed that, on the average, the larger individuals in the Magothy would be more prone to move longer distances than smaller fish, as has been observed among striped bass (Mansueti, 1958:22).

Salinity is an important factor in the distribution of estuarine fish. Differences in this factor at the river mouths during spring and early summer, when the greatest dispersal occurred, could account for the variable migratory behavior. In general, these differences would amount to only 2 or 3 ppt, where the average salinity is generally about 6 ppt during spring, according to Whaley and Hopkins (1952: see cruise data for April, May and July, 1950). Yellow perch in Chesapeake Bay are euryhaline, and are known from salinities of almost 13 ppt (Hildebrand and Schroeder, 1928:237), which is somewhat higher than that recorded at the mouth of the Severn River. If the relatively freshwater subpopulation of yellow perch from the Chester River was unable to tolerate the higher salinities of the Severn and Magothy, it would have remained upstream in tidal fresh water. Actually, the majority of fish seemed to ignore salinity. Thus, it is unlikely that this factor would account for the differences in dispersal pattern. Salinity did not seem to be an important factor in the down-bay movement of fish, although more of the movement was up-bay (Fig. 4 and 5).

Direct evidence for acclimatization is fragmentary. Sight records of a tagged fish on the Severn Run spawning grounds and a tagged fish on the Magothy River spawning grounds were recorded in March 1956, indicating that possibly some of the Chester River fish were assimilated early by breeding residents. Both rivers produced stocked fish in 1957 (8 in the Severn and 4 in the Magothy), while in 1958 the Severn yielded 4 fish, 2 to anglers and 2 to a scientific netting experiment.

Factors affecting dispersal:—Suggestions of the factors bringing about the spectacular dispersal from the two river systems can be found in the literature that deals with the displacement of animals from their so-called home area. In general, stocking and displacement of vertebrates of most types may bring about unexpected results. Moreover, the introduction of a displaced species into an established population of the same species creates intraspecific conflicts that have important biological and management implications.

A considerable literature exists on the "put and take" stocking of adult fish in inland waters. It should be noted that these are virtually all hatchery fish; there is some data on transplantation of adult wild fish for experimental purposes. Rounsefell and Everhart (1953:373–4) properly emphasized that stocked fish are removed so rapidly by high angling pressure that they have little opportunity to disperse. If not removed immediately, they wander aimlessly and sometimes far from the stocking sites. Although angling harvest accounts for considerable mortality of stocked fish, unfavorable environment, unfamiliarity with landmarks of a new habitat, and perhaps intraspecific conflicts may account for many of the losses cited by Thorpe, et al (1947:166–87), Hess (1954:44), and Schuck (1948:3–14).

Conflicts may arise among different subpopulations of fish of the same species but of

different geographic or genetic origin when thrown together. Also, unusual behavior between species may occur after introduction, even though they may be adjusted to one another in a habitat uncontaminated by stocking. Such a relationship among fishes has never been carefully described in the literature, although Hill (1956:92–4) provided some brief observations that are pertinent. When new fishes, such as mullet, red snappers, grunts, or triggerfish, were introduced into the huge tanks at the oceanarium at Marineland, Florida, they darted around nervously, and exhibited other behavior patterns that attracted predators. The newcomers were chased vigorously, attacked, and even devoured. Even though the same species of the same size were already present, these were not usually molested. If the new fishes survived the first few days and gradually acclimatized to the strange surroundings, the predators, such as barracudas, jack crevalles, tarpon, and porpoises, lost their intense interest in them. Also, when small fish of one species became acclimatized, subsequent introductions of large individuals of the same species did not alter the dominant role of the small fish. When still larger fish were introduced singly, the smallest one became more and more aggressive and still remained the dominant individual.

A more spectacular example of the effects of introducing a displaced population of a mammal species into an established one, although far removed from fishes, is given by Calhoun (1948:167–72), Davis (1949:225–31) and Davis and Christian (1956:378–83). The latter workers introduced alien Norway rats into stationary and increasing populations in city blocks. The introductions disrupted the population mechanisms so that the numbers of resident rats declined and stopped growing, respectively. Fighting and competition between the aliens and residents brought about substantial movement and mortality. Flyger (1955:387–8) introduced alien gray squirrels marked with dyes into an established population, and found that they were bewildered and moved about erratically. Virtually all quickly left the woodlot, however, without conflict with the residents.

It is difficult to evaluate the dispersal of stocked yellow perch in terms of the phenomena mentioned above. They suggest, however, that these factors may always be effective when alien fish are stocked into an established population, and that pertinent experimental evidence should be obtained. Of some importance is the possibility that instead of increasing the population either directly or eventually by reproduction, stocking alien fish may disrupt the resident population so that a decline in abundance may occur under certain conditions, as suggested for mammals by Davis and Christian (1956:383). It is conceivable that if a resident population is at a very low ebb, or above the halfway point on a growth curve, the stocking of a number of fish may bring about disastrous results.

Dispersal out of the rivers suggests that fish may have attempted to return to their stream of origin in the Chester River. Fig. 4 and 5 shows that virtually none did so. The few successful ones probably entered the river accidentally, although Hasler, et al (1958:355) indicated that random searching cannot be discounted as a possible mechanism of return. There is a growing body of evidence to show that fish have extraordinary powers of homing, with varying degrees of success, when they are not displaced too far from their home site. Gerking (1959:221–42) and Gunning (1959:103–20) provided a thorough review of homing in fish, and only several examples need be given here. Hasler and Wisby (1958:289–93) showed that displaced green sunfish and largemouth bass can return to the site of original capture. Many factors, such as age and sex of the individual, presence and absence of landmarks within their geographic displacement, and season of the year, can affect the speed and accuracy of return of a displaced fish. If it is assumed that the Chester River supports a relatively self-contained population, in that little emigration occurs, then it is certain that they could not have learned any of the identifying bottom features of Chesapeake Bay between the home river and the Severn and Magothy. The displacement area and distance in relation to home site are important features in homing. Larimore (1952:11)

displaced 50 longear sunfish relatively far from their point of origin, but only nine returned home, whereas a significant number of displaced smallmouth bass moved toward home accurately and in a short time after being moved less than a mile. Gunning (1959:123–5) concluded by elaborate experiments that homing in the former species was mediated by the olfactory mechanism, especially those fish homing in an upstream direction. Gerking (1953:364) also concluded that the homing ability of the longear sunfish was improved when they were displaced a shorter distance. Shoemaker (1952:86) showed that pumpkinseeds would return to home areas while a small number strayed when displaced too far to other areas of the lake.

Hasler and Wisby (1958:291–3) stated that displaced largemouth bass in a 15-acre lake did not return to their capture-area with the same precision as that seen in the green sunfish. They postulated that this might be due partly to the lack of easily visible landmarks within the waters of the deeper, rather dark, lakes in which their experiments were conducted, as well as to the longer distances which they had to traverse. Hess (1959:37–8) found that a higher percentage of returns to the home streams by cutthroat trout, displaced one to four miles from where originally trapped, indicated a strong homing tendency. Miller (1954:557) found that the same species transplanted downstream and upstream also will attempt to return to their home areas, but about one-third of the latter failed, as reported for longear sunfish by Gunning. Cutthroat trout transplanted from either upstream or downstream seemed to lose their "memory" of home after 30 or more days in a new area. Thus homing ability seemed to be a function of distance. According to Miller, the 30-day "adjustment" period coincided with the often observed tendency of hatchery-reared fish to drift and be subject to easy capture for 30 or 40 days after planting in a stream. Most of the above examples suggest that the sense of smell and sight would be important factors in homing of yellow perch in an estuary. They also suggest that if the fish are stocked too far from the home site, these factors would be useless to a population that had not had an opportunity to become conditioned to the new landmarks or the gradient of odors between the stocking area and capture-area.

Another interesting phenomenon that might help in the interpretation of the yellow perch movements is sun-compass orientation which is coordinated with a biological clock. It has been postulated by a number of authors and investigated by Hasler, et al (1958:353–61) that a fish's ability to return to its place of origin would be facilitated if it had a built-in compass and chronometer as well as a sextant to aid in direction finding and in determining geographic location. Once in the general area of home, familiarity with combinations of visual, tactile and olfactory features could direct it more precisely. With such mechanisms it could correct continuously to forces which drift it off course. They found that white bass, displaced about one to two miles from their spawning grounds in the lake, were aided by the sun in open water in their successful return to the site of origin. Stuart (1957:24–5) transported brown trout from one tributary stream to another across a reservoir and found that 30 out of 113 fish returned, one-half with their nasal pits plugged and one-half controls. It may be concluded that the sun served as a point of reference in these examples, and that the animals compensated for their movement by a biological chronometer. It is purely speculative whether estuarine yellow perch utilize sun-compass orientation in their migrations, but the great distances between the stocking and home sites may have mitigated its value.

In spite of the value of hypotheses in explaining fish movements, there is little evidence to suggest why the yellow perch failed to return successfully to the parent stream. Hasler and Wisby (1958:293) have suggested that distance of displacement is the most compelling reason why many displaced fish do not return to their parent stream. A fish could be moved to a point so far from its home area that it would be unable to return, as sometimes happens with trained pigeons. This possibility is dependent on the size of the body of water and the in-

herent homing ability of the species and individuals involved. When the relatively great distance of 25 to 30 miles between stocking and home sites are compared with literature reports of less than one mile to five miles traveled by displaced fish, and with variable success in homing, it seems clear that most of the displaced yellow perch were too lost ever to find their way back to the home area.

Conclusions

(1) Displaced yellow perch, originally from the Chester River and introduced into two tributaries 25 to 30 miles to the west in upper Chesapeake Bay, did not remain in the river of stocking, nor did they return to the site of their original capture. They dispersed widely into areas in the bay with a salinity range from tidal freshwater to 12 ppt. Of 995 fish stocked in the Severn, 17 percent were recaptured, while of the 1038 stocked in the Magothy, 25 percent were recaptured by all fishermen.

(2) Movements of stocked fish in the Severn River differed from those of the resident population. Resident fish rarely strayed from the river, but within the Severn they undertook extensive seasonal migrations for spawning and feeding. Stocked fish in the Magothy River showed a dispersal pattern similar to those stocked in the Severn.

(3) Magothy and Severn anglers, for whom the fish were stocked, took fewer recaptured fish (18 and 47 percent, respectively) than did commercial netters operating in Chesapeake Bay. They accounted for only 7 and 4 percent of all tagged stocked fish, respectively, whereas of all tagged resident fish within the Severn, where commercial netting is illegal, anglers accounted for about 10 percent.

(4) A small, but unknown, number of stocked fish remained within the Severn and Magothy Rivers for over two years and were presumably acclimatized. Stocked fish were also apparently acclimatized to various localities in Chesapeake Bay, since tags were returned during 1957 and 1958.

(5) Homing was not accomplished by the displaced fish since they were transported too far from the Chester River. Factors which influence displaced fish are complex and merit further study.

(6) As a management measure, the "put and take" stocking of adult estuarine yellow perch into strange waters appears to be of doubtful value.

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Stormy Fermenters and Coliform Bacteria in the Soft-Shelled Clam *Mya arenaria* and its Habitat[1]

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ABSTRACT

Enumerations were made of coliforms, "*Escherichia coli*" and stormy fermenters, (presumably *Clostridium perfringens*), as indicators of fecal pollution in the soft-shelled clam, *Mya arenaria*, and in its habitat, through a seasonal cycle. Stormy fermenters showed a pattern similar to coliforms and "*E. coli*" in clams, but no similarities were observed among these organisms in the overlying waters, the sediment-water interface or the sediments. When examined as a function of temperature, none of the indicator microorganisms showed marked seasonal trends in bacterial density. Stormy fermenters apparently did not produce any false positive coliform reactions during the course of this study.

Introduction

Shellfish production has expanded into many new areas in the past decade. In some of these areas, especially in the more southern waters of the United States, it has been found difficult to meet minimum bacteriological standards from a public health standpoint. This has led to an examination of the validity of bacteriological criteria for the marketed products. This subject was discussed recently by sanitarians from nearly every shellfish producing area of the United States in the 1958 proceedings of the USPHS Shellfish Sanitation Workshop.

As one part of an investigation into the microbiology of the soft-shelled clam, *Mya arenaria*, and its habitat, populations of stormy fermenters were estimated and compared with coliform and "*Escherichia coli*" populations. The term "*E. coli*" denotes bacteria giving positive results in Difco EC confirmatory medium at 44.5°C. Stormy fermenters are anaerobic, sporeforming, lactose-fermenting bacteria. As determined by their behavior in skimmed milk and by subsequent microscopic examination, they are presumably *Clostridium perfringens* (= *Cl. welchii*).

Stormy fermenters were estimated for two reasons: (1) these bacteria can ferment lactose, consequently they have been known to produce false positives in coliform determinations (cf. Prescott, Winslow, and McCrady, 1947:80–81); and (2) to observe their characteristics as indicators of pollution in the soft-shelled clam and its habitat through a seasonal cycle, as compared with coliforms and "*E. coli*".

British sanitarians have continuously placed more confidence in stormy fermenters as indicators of fecal pollution than have American investigators (Prescott, Winslow, and McCrady, 1947; APHA Standard Methods for the Examination of Water, Sewage and Industrial Wastes, 10th ed.; Taylor, 1958). While stormy fermenters do not supersede or replace coliform determinations, they are viewed as ancillary means of evaluating water quality, and are presumed to be indicative of intermittent pollution if coliforms are absent.

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Materials and Methods

A soft-shelled clam bed near the entrance to Solomons harbor, in the mouth of the Patuxent River, Chesapeake Bay (38° 19′ 10″ N., 76° 26′ 50″ W., USC & GS chart #561), was used for sampling *M. arenaria* and its habitat through one seasonal cycle. The water depth over this bed was approximately four feet, and salinities ranged from 7 to 17.5‰. The bottom sediment is a coarse sand, aerobic in the top centimeter or two, and below that exhibiting black sulfides indicating an anaerobic environment.

This area was selected for its convenience to the laboratory and for the degree of pollution found. The Maryland State Health Department aided the efforts greatly by performing routine water quality sampling in the region, as well as by executing a shoreline survey of the drainage area that affects these waters.

Each analysis of *M. arenaria* and its habitat included samples of (a) overlying waters, (b) sediment-water interface, (c) sediments, and (d) clams. Samples were taken monthly.

Water samples were taken aseptically in sterile 125 ml glass-stoppered bottles held in a specially-fabricated brass sampler that can be lowered to the desired depth and opened and closed *in situ* by a release line.

Sediment-water interface samples were taken by skin diving to the bottom with an 11 mm i.d. sterile glass tube, stoppered at both ends, removing the bottom rubber stopper, and controlling intake with the upper rubber stopper.

Sediment samples were taken by skin-diving to the bottom with a 17 mm i.d. sterile glass tube stoppered at both ends, removing the rubber stoppers and taking a core manually. The stoppers were replaced under water and the sample retrieved. A few attempts were made to core with a conventional 1¼″ plexiglass-lined core sampler, but the sediments were too coarse to be compacted satisfactorily, and this procedure was abandoned.

Clam samples were taken by a commercial-type hydraulic clam dredge, described by Manning (1957). Sterile rubber gloves were used at all times in handling the clams, placing them in sterile 32 oz wide-mouth jars.

Preparation of water and clam samples for bacteriological examination followed the outline reported by Kelly (1958) in a cooperative study to evaluate bacteriological criteria of shellfish. Coliform and "*E. coli*" MPN determinations were made according to this outline, which adheres to "Standard Methods for the Examination of Water, Sewage and Industrial Wastes," APHA (1955).

Stormy fermenters were estimated with the 5-tube MPN technique, described and discussed in "Standard Methods." Sterile skimmed milk was used for the medium. After inoculation, sterile, melted "vaspar" (one part paraffin, four parts vaseline) was carefully layered to a depth of at least ½ inch over the medium in each culture tube. All tubes were then placed in an 80°C. water bath for 15 minutes. Incubation was at 35°C for four days. Positive stormy fermenter reactions were checked microscopically on several occasions for the typical morphology of *Clostridium*. No confirmatory cultural procedures were used.

Results

This paper compares the population levels of stormy fermenters with coliform and "*E. coli*" in *M. arenaria*, the overlying waters, the sediment-water interface, and the sediments.

Fig. 1 shows the logarithm of the numbers of stormy fermenters per 100 ml (or 100 gm) on the abscissa, plotted against the logarithm of the numbers of coliforms and of "*E. coli*" on the ordinate. Fig. 1A shows data for the overlying waters, Fig. 1B for the interface, Fig. 1C for sediments, and Fig. 1D for the clams.

Fig. 1A indicates that, while coliform and "*E. coli*" were frequently found in appreciable numbers in the overlying waters, stormy fermenters were rarely found there.

Fig. 1B shows an irregular relationship between these microorganisms at the sedi-

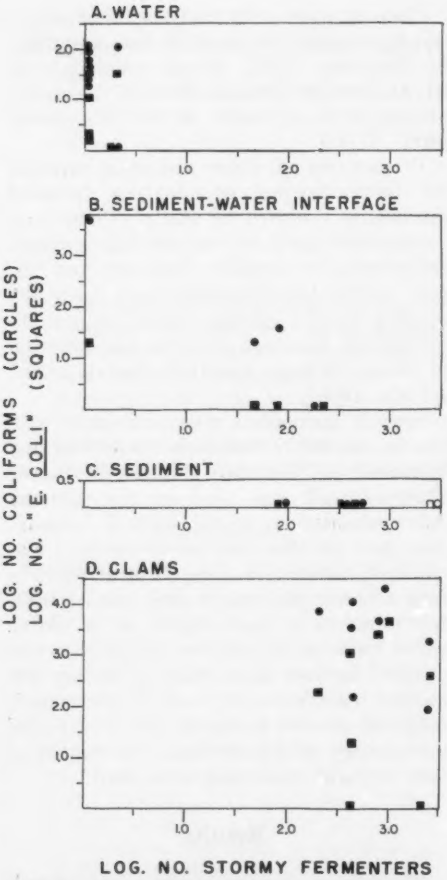

Fig. 1.—Comparison of the relative populations of stormy fermenters with coliforms and *"E. coli"* in the soft-shelled clam, *Mya arenaria*, and its habitat.

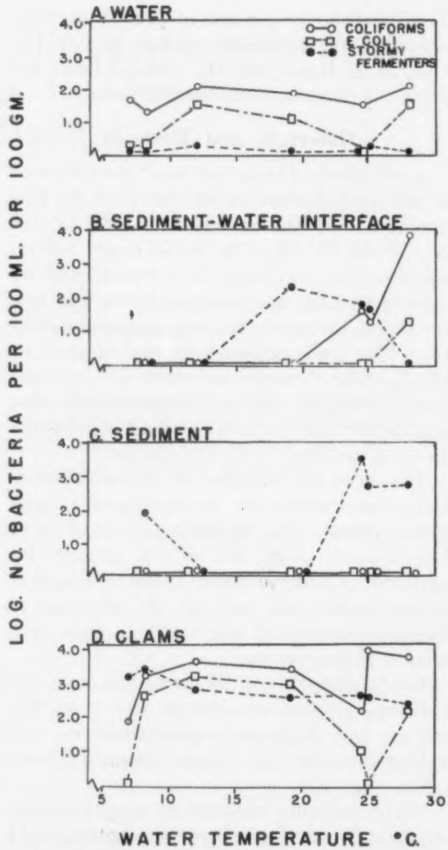

Fig. 2.—Comparison of bacterial indicators in the soft-shelled clam, *Mya arenaria*, and its habitat through a seasonal cycle.

ment-water interface, with high values for each found in the absence of the other, but on two occasions a nearly coincident relationship.

In the sediments, Fig. 1C, no coliforms or *"E. coli"* were found, while stormy fermenters were consistently detected. This can be attributed to the resistant spore stage of the clostridia, which is capable of withstanding the anaerobic, sulfide-containing environment.

A general coincidence between these indicator organisms is found in clams, shown in Fig. 1D. Coliforms were usually abundant and *"E. coli"* were more irregularly distributed. Two factors can account for this distribution, *viz.*, (1) "coliforms," at least theoretically, include *"E. coli"* as well as other enterobacteria, and would therefore show greater numbers, and (2) the lower values for *"E. coli"* could be due to determinative error. The *"E. coli"* test is dependent upon very critical temperature tolerances, which, in some cases, may not have been accurately realized.

Fig. 2 shows the observed relationship, or lack of relationship, of these indicator organisms (ordinate) and water temperature (abscissa), which varies seasonally.

These plots show the same general pat-

tern as Fig. 1, i.e., (a) coliforms and "*E. coli*" much higher in overlying waters than stormy fermenters; (b) an irregular pattern in the interface; (c) the absence of coliforms and "*E. coli*" in sediments, but with stormy fermenters generally detectable, and (d) all the indicator organisms present in clams.

Discussion

The bacteriological quality of shellfish growing waters is commonly used as an index to the sanitary quality of the shellfish therein. Water quality tests are usually supplemented by tests of the shellfish themselves before marketing.

The most commonly used indicator organisms are the coliforms, defined as "all of the aerobic and facultatively anaerobic Gram negative non-sporeforming bacilli which ferment lactose with gas formation within 48 hours at 35°C." (Standard Methods, 1955). These presumably are all included in the family Enterobacteriaceae.

Escherichia coli is regarded as a normal inhabitant of the intestinal tracts of warm-blooded animals, and the presence of this organism in waters or shellfish indicates fecal pollution. Another coliform, *Aerobacter aerogenes* is the so-called "grain organism," a normal inhabitant of soils, grasses, etc., as well as in the intestinal tracts of warm-blooded animals, but usually in far fewer numbers than *E. coli*. (Griffin and Stuart, 1940). There are related "intermediate" organisms, giving different diagnostic reactions from *E. coli* or *A. aerogenes*. The test for coliforms, as usually practiced, does not discriminate between coliforms of "fecal" and "non-fecal" origin.

In recent years, the development of a relatively rapid and reliable test for the presence of *E. coli* has led to the evaluation of this test as a means of indication and control in shellfish sanitation (Proceedings, Shellfish Sanitation Workshop, 1958). This test presumably indicates the presence or absence of fecal coliforms.

Stormy fermenters have been studied as a possible indicator organism in water (Greer, 1928; Prescott, Winslow and McCrady, 1947; Willis, 1956), but there seems to be no literature relevant to the use of this organism in the sanitary engineering of shellfish. There is not universal agreement concerning the validity of this organism as an indicator of fecal pollution (*cf.* Gainey and Lord, 1952), but it seems to have value as a supplementary indicator when used with conventional techniques (Taylor, 1958).

Comparison of Indicator Organisms

Stormy fermenters are not as sensitive indicators of fecal pollution, as judged by population levels, as are coliforms and "*E. coli*" in the habitat of *M. arenaria*. In the clam itself, the relationship between these criteria seems to be good, but several factors must be borne in mind in interpreting these data.

1. The test for stormy fermenters estimates population levels of spore stages only, the vegetative cells presumably being destroyed by the 80°C temperature for 15 minutes. The total population of clostridia, including the spore stages, would not, therefore, be expected to behave like a population of nonsporeforming microorganisms as are the coliforms. This condition is reflected in the tendency for lesser numbers of spores with increasing temperature, while population trends of coliforms and "*E. coli*" tend to increase with temperature, (Fig. 2D). The downward trend of spores could be due to increased "hatching" of spores, with more vegetative cells in the environment. The irregular levels of stormy fermenters in sediment-water interface could be due to an actual irregular distribution spatially on the clam flats, or to the sampling techniques used for interface and sediments.

2. *M. arenaria* normally lives buried within the sediments, with only the tip of the snout at the interface. With such intimate contact of clam and sediment, it is not surprising to find stormy fermenters in appreciable numbers in both the clam and sediments.

3. Another aspect to be considered when comparing sporeformers with nonsporeformers is the resistance of bacterial spores, as compared with vegetative cells, to antimetabolites, antibiotics, and adverse physical and chemical conditions that can occur in the clam and in the environment. This

would cause the relative populations to show differing behavioral patterns.

Seasonal Changes

Some investigators (Gibbard, et al, 1942; Bidwell, 1940) have found increasing bacterial populations with increasing water temperature. Other authors (Clague and Almario, 1950; Perry, 1928; Fisher and Acker, 1935) have found no good correlations between season and bacterial density.

The results shown in Fig. 2 show no definite pattern of bacterial density with respect to temperature, in the range of 7°C to 28°C.

False Positives

In the course of these investigations, all positive presumptive lactose tubes for coliforms were confirmed in brilliant green lactose bile broth, or in the "EC" medium for "*E. coli.*" The completed test was done on EMB medium. All organisms were also diagnosed with the IMViC series of tests. More than 250 such examinations were made, and in no case were stormy fermenters encountered as giving false positive coliform reactions from the clam or its habitat. The IMViC results will be reported in detail in a later paper.

Conclusions

Stormy fermenters may have value as an ancillary indicator of fecal contamination in the clam *Mya arenaria*, but probably have little indicative value in the environment, i.e., overlying water, sediment-water interface, or sediments, at the levels of pollution found in these investigations and in this particular habitat.

A practical note, unrelated to public health but closely related to food technology, concerns the prevalence of sporeformers in clams. This implies a high level of heat processing is required in cooked-canned clam products.

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Creel Census Results on the Northeast River, Maryland, 1958[1]

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ABSTRACT

Fishing pressure in the Northeast River, a freshwater tidal tributary of Chesapeake Bay, was very light in 1958. Only 2.4 trips per acre were estimated for the five month period, June through October. Data, collected by one field man who interviewed and counted anglers daily, indicated that the rate of harvest was 0.29 fish per man hour, and that the average catch (keepworthy fish only) amounted to 1.5 fish per fishing trip. Channel catfish, largemouth bass, white perch and yellow perch, in that order, were the most important species in the creel.

Introduction

One of the most important unknowns in Maryland fish management is the extent of the angling pressure and the harvest of sport fishes from the Chesapeake Bay and its tidewater tributaries. Techniques are available for estimating these figures, but the cost of collecting the necessary data seems prohibitive. Unpublished estimates indicate that a reliable estimate of these figures would cost about $90,000 annually. However, a small amount of work has been done on two tributaries: Walker (1954), on the Patuxent River; and Elser (1957A), on the Magothy River. In both cases, creel censuses were designed to estimate total pressure and harvest.

In early 1958, plans were made to study the effect of the removal of large numbers of largemouth bass, *Micropterus salmoides*, from the Northeast River, a tidewater tributary of Chesapeake Bay. An estimation of the angling pressure and harvest of sport fishes was deemed essential to this study, and a five-month creel census was begun on the opening of bass season, June 1, 1958. This report concerns only the creel census and its results.

I wish to thank the many people who aided this study and express particular appreciation to the Maryland Game and Inland Fish Commission who bore most of the financial burden, and to Mr. Guy Rogers who supervised the day-to-day operation of the project.

Description of Area

The Northeast River, in Cecil County, Maryland, is the northern-most tidal tributary of Chesapeake Bay. Its area is about 4,000 acres measured from a line running from Carpenter Point to Red Point (see Fig. 1). The normal maximum depth is about 20 feet in a narrow channel running along the east side of the river near the mouth but gravel dredging at Arundel Pit has created a hole with a depth of about 70 feet. The tidal amplitude is approximately two feet. The water is virtually fresh, having a maximum salinity in dry years of less than one-half part per thousand.

The waterfront property is moderately developed as a residential area; about half of the shoreline is in woodlands and fields, the other half in residences and resorts. There are five large marinas on the river, four or five boat liveries, nine or 10 swimming beaches, no public parks and no free public access at which boats may be put in the water. An important item, from the anglers' viewpoint, is that the river is an extremely popular boating area and large numbers of power boats are kept there.

There are two small towns adjacent to the river; Northeast with a 1950 population of 1,570 and Charlestown with 550 people. The

[1] Contribution No. 136, Maryland Department of Research and Education, Solomons, Maryland.

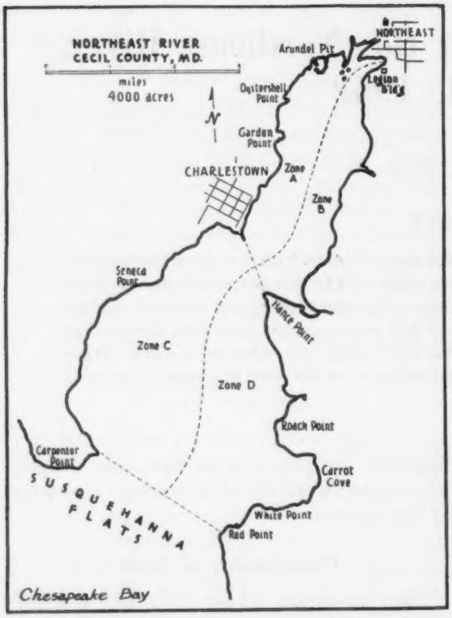

Fig. 1.—Creel census zones in the Northeast River, Maryland.

total population within five miles of the river is approximately 5,000.

Immediately to the southwest of the river and in the bay proper are the Susquehanna Flats. This vast area of shallow water with very abundant submerged vegetation is famous as the wintering ground of hordes of migratory ducks. It is highly regarded as a fishing spot for many species of fish, but especially the largemouth bass. This area was not included in the creel census but it is believed to have an important effect on the fishing pressure of the Northeast River, particularly during bad weather. This is because the Flats are difficult to fish during heavy winds, so that angling at these times is largely confined to the more sheltered tributaries, such as the Northeast River.

Methods

The creel census started June 1 and ran through October. The field work was done by one man, who, working according to a rigid plan, interviewed anglers while they were fishing. Once each day, at scheduled times, he stopped interviewing and, traveling by boat, counted all the fishermen on the entire river. The usual times for counting were 10 o'clock in the morning and 2 o'clock in the afternoon, because experience on Maryland waters has shown these to be the most reliable times for counting anglers, i.e., there is the least day-to-day variation, proportionately.

In those cases when the fisherman was not through for the day, the interviewer gave him a self-addressed reply card and asked that he fill it out and mail it in when he was through fishing. The card, which is similar to those used in other Maryland creel census work, consists of a form listing a number of possible species which might be caught and spaces in which to enter the number kept, the number thrown back and the time fishing ended. The card is numbered to correspond with the original page in the field-data book and when it arrives at the laboratory is used to complete the record of the fisherman's luck. The data are used for computing the average number of fish taken per trip and the average number of hours spent per trip. The counts of fishermen recorded by the field man are used as the basis to estimate the number of fishermen fishing on the river for the day of the count. The estimate is made in this manner: the reply cards, which give the period of the day fished by each angler (who sends in a card), are assembled and the periods of fishing are drawn as lines on a graph. A line drawn, say, from 8 AM to noon represents one party fishing for that period. Then, by adding the number of parties fishing, say between 8 and 9 AM and those between 9 and 10 AM and so on, the proportion of the day's fishermen who were fishing on the river at the time of the count can be readily determined. In most Maryland creel censuses this turns out to be about 40 percent at 10 AM and about 45 percent at 2 PM.

The estimates of the total fishermen for each of the days that counting runs were made are averaged by day of the week (average of the Sundays, of the Mondays, etc.). Blank spaces, representing days when counts are not made (because of days off, motor trouble, etc.), are filled in with the

appropriate estimates. A further refinement is possible by converting the averages for each day of the week into percentages of the average week's fishing. Then the blank spaces can be filled in according to the general level of the period during which the space occurs. For instance, a blank space, say a Wednesday, near the beginning of the season will be filled in with an estimate larger than for a Wednesday late in the season because the number of fishermen per week is larger early in the season. The filling of blank spaces, then, depends on two factors: position in the week and position in the season. By adding the estimates for all the days of the season, an estimate of the total number of man-days spent fishing will be obtained. Very few of the estimates for individual days will be close to the true value; some will exaggerate, others will depreciate, but the total of all of them will probably be reasonably accurate.

The average number of fish per trip, a statistic produced from the interview phase of the census, is multiplied by the estimate of the total number of trips to yield an estimate of the total catch of fish. This catch is broken down by species according to the proportions reported on the reply cards.

TABLE 1.—Excerpt from working schedule of creel census field man, Northeast River, Maryland, First two weeks of June, 1958.[1]

Schedule, Coded

Week of	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
June 1	a1	b2	c3	d4	X	e5	a6
June 8	b7	c8	d1	X	e2	a3	b4

X = Day off (Every sixth day except for week-ends).

Code

Code symbols	Working hours*	Start count at	Counting route zones	Start at	Interview zones before count**	Interview zones after count
a1	6 AM–2 PM	10 AM	A-B-D-C	Charlestown	B-D-C	A
a3	6 AM–2 PM	10 AM	C-D-B-A	Charlestown	D-B-A	C
a6	6 AM–2 PM	10 AM	B-A-C-D	Hance Point	A-C-D	B
b2	12 N–8 PM	2 PM	B-D-C-A	Legion Bldg.	A	B-D-C
b4	12 N–8 PM	2 PM	D-B-A-C	Red Point	C	D-B-A
b7	12 N–8 PM	2 PM	C-A-B-D	Carpenter Pt.	D	A-B-C
c3	8 AM–4 PM	10 AM	C-D-B-A	Charlestown	A	C-D-B
c8	8 AM–4 PM	10 AM	D-C-A-B	Hance Point	B	D-C-A
d1	2 PM–10 PM	2 PM	A-B-D-C	Charlestown	—	A-B-D-C
d4	2 PM–10 PM	2 PM	D-B-A-C	Red Point	—	D-B-A-C
e2	10 AM–6 PM	10 AM	B-D-C-A	Legion Bldg.	—	B-D-C-A
e5	10 AM–6 PM	10 AM	A-C-D-B	Legion Bldg.	—	A-C-D-B

* Do not census before dawn or after dark even when schedule calls for it. (Safety)

** If you contact all anglers in interviewing zones before the count, do not interview in post-counting zones until after count is completed.

NOTE: Follow this schedule rigidly—do not substitute. If bad weather, motor trouble or some emergency prevents working, do not try to put that day's schedule in some other day.

[1] Explanation: Code letters refer to field man's working hours; code numbers refer to counting routes. Notice that a1 and d1 have different hours but same counting route. Five different working hours and eight different counting routes allows for 40 different patterns, enough, it is felt, to ensure representative coverage of all hours of the day and area of the river. For locations of zones and places, refer to Figure 1.

Collection of data was on a systematic basis so that as many variables as possible could be neutralized. Some days the field man started work at 6 AM and on other days not until 2 PM. His schedule fixed the part of the river and the period during which he was to interview, the time of the counting run and the direction of travel. In the case of rain or extremely windy weather he carries on as has been prescribed, even though he sees no fishermen or knows that none are active at the time. Table 1 is a sample of his schedule. There were 40 different working patterns using eight counting routes and five different working hours. This scheme allows for study at all times of the day and removes much bias which might be introduced by working one part of the area more than another. After Labor Day the field work was cut down to an every-sixth-day census in the belief that fishing pressure would then become much lighter. This belief was mistaken as will be discussed below.

Results and Discussion

Fishing pressure proved to be very light on the Northeast River. During the five-month period, June 1–October 31, there were an estimated 9,500 fishing trips. On a per-acre basis, this is the lightest angling pressure that has so far been measured on any Maryland water. Significantly, the next lightest pressure was found on another tidal tributary, the Magothy River.

Table 2 demonstrates the position of the two rivers in the scale of pressure values. It was prepared from creel census data in the author's files and is selected only to the extent that it does not include streams. The data have also been selected to include only the fishing pressure which occurred between June 1 and Labor Day. This is probably the shortest period which conveniently can be used for comparing pressure between areas. It has the advantage of including the bulk of the season's fishing (except on trout streams) but does not always cover the peak fishing period.

TABLE 2.—Estimated fishing pressure on several bodies of water, by trips per acre, Maryland, June 1 through Labor Day, various years, 1951–1959.

Place	Acres	Year of Study	June 1 thru Labor Day	
			Number of Trips	Trips per Acre
Northeast River[1] Cecil County	4,000	1958	5,400	1.4
Magothy River[1] Anne Arundel County	5,200	1957	11,400	2.1
Loch Raven Baltimore County	2,500	1952	6,700	2.7
Conowingo Reservoir Cecil County	5,100	Average of 2 years 1955 and 1957	15,200	3.0
Deep Creek Lake Garrett County	3,900	Average of 8 years 1951 to 1959	15,600	4.0
Urieville Lake Kent County	35	1957	187	5.4
Triadelphia Reservoir Montgomery County	870	Average of 2 years 1951 and 1952	7,500	8.6
Wye Lake Queen Anne County	45	Average of 2 years 1958 and 1959	640	14
Greenbelt Lake Prince Georges County	22	Average of 2 years 1953 and 1959	2,600	120
Lake Waterford Anne Arundel County	11	1957	1,400	130
Hughesville Community Pond Charles County	1¼	1957	880	700

[1] Tidal Tributary of Chesapeake Bay.

Area of the water is an important factor in fishing pressure. There is a fairly good negative correlation between pressure and area as can be seen from Table 2. The heaviest fished places are those with the smallest areas. Hughesville Community Pond with an area of only one and one quarter acres supported 700 trips per acre and it is believed that two or three other small ponds in Maryland support even more.

Fishing pressure is never applied evenly over the area of any body of water. The type and depth of the bottom, the distribution of weed beds, the direction and speed of the wind, the location of concentrations of fish and the proximity of access points are some of the factors which determine the distribution of fishermen. In the Northeast River in 1958, the heaviest concentration of angling was at the top of the river, especially in the area near the Arundel gravel pits. The lightest pressure was in the broad open reaches of water in the middle of the river. Fig. 2 shows the approximate distribution and degree of fishing pressure for the three summer months of 1958. The map was prepared from data collected by the creel-census field man. As he made his counting runs, he put tiny check marks on a map at the approximate location of each fisherman he counted. Then, by placing a transparent overlay sheet provided with grid lines over the field maps, the anglers' fishing in each section of the grid were counted. Contour lines of pressure were estimated and drawn by eye from these data.

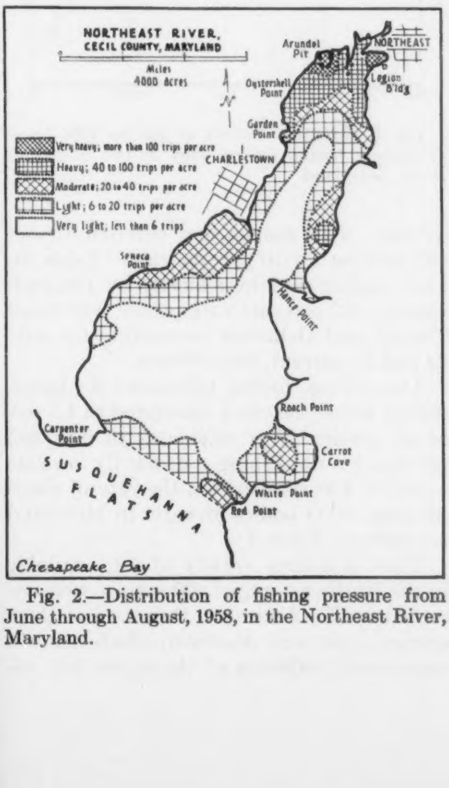

Fig. 2.—Distribution of fishing pressure from June through August, 1958, in the Northeast River, Maryland.

Fishing pressure varies also with the time of the year. Generally, more fishermen are active on the opening day of a season (April 15 for trout and June 1 for black bass) than at any other time. Except for these special days, the peak of fishing pressure may be in May (Conowingo-Susquehanna area in 1957), June (Loch Raven in 1952) or July (Magothy River in 1957) (see Elser 1953 and 1957B). In the Northeast River in 1958 the peak of pressure was during the first week of June, after which it declined gradually to a low in early August. Following that week, pressure rose to a strong peak in mid-September and declined until the end of the census period. This is shown as a curve in Fig. 3. The strong peak in September was not anticipated and a light creel-census effort was planned for September and October. Therefore, the estimates for September and October are subject to much greater sampling error than are those for the first three months.

About 80 percent of the fishing was done

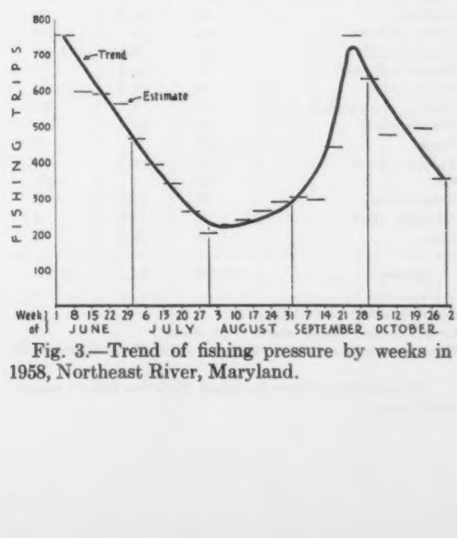

Fig. 3.—Trend of fishing pressure by weeks in 1958, Northeast River, Maryland.

TABLE 3.—Fishing pressure and harvest, northeast River, Maryland, as estimated by creel census, June 1 through October 31, 1958.

Fishing Pressure

Total fishing trips			9,500
		percent	
by men	7,600	80	
women	920	10	
children	990	10	
Trips per acre			2.4
Total number of hours fished			51,000
Average hours per trip			5.1

Residence of anglers

	Per-cent		Per-cent
Pensylvania	62	Virginia	<0.5
Cecil County, Md.	21	West Virginia	<0.5
Delaware	11	New York	<0.5
Baltimore County, Md.	2	Florida	<0.5
Baltimore City	1	Ohio	<0.5
New Jersey	1	Missouri	<0.5
Harford County, Md.	<0.5	Wisconsin	<0.5
Anne Arundel County	<0.5	Utah	<0.5
		South America	<0.5

Harvest

Fish harvested per man-hour	0.29
Thrown back, per man-hour	0.36
Total, per man-hour	0.65

	Estimated catch, by species[1]		
	Kept	Percent	Thrown back
Smallmouth bass	100	1	140
Largemouth bass	2,800	19	1,900
Black crappies	1,200	8	600
White crappies	50	<0.5	10
Bluegills	250	2	250
Green sunfish	10	<0.5	—
Sunfish, unidentified	570	4	640
Yellow perch	2,200	15	4,300
White perch	2,600	18	7,700
Walleyes	50	<0.5	40
Chain pickerel	480	3	140
Channel catfish	3,600	25	1,400
Yellow bullheads	18	<0.5	—
White catfish	50	<0.5	—
Catfish, unidentified	170	1	360
White suckers	10	<0.5	—
Carp	310	2	10
Golden shiners	20	<0.5	60
Eel	170	1	600
Striped bass	20	<0.5	45
American shad	10	<0.5	3
Spot	40	<0.5	25
Totals	14,600	100	18,300

Number of fish harvested per acre 3.6
Length of creel census season 22 weeks
Number of fishermen interviewed 2,315 (about 24 percent of total)

[1] Nomenclature follows American Fisheries Society recommendations.

TABLE 4.—Various creel census statistics from some Maryland waters, 1951–1958.

	Fish Harvested per man-hour	Average Catch per trip	Average Hours per trip	Number of species caught
Northeast River, 1958	0.29	1.5	5.4	20
Magothy River, 1957	1.8	8.2	4.5	18
Conowingo-Susquehanna area, 1957	0.57	3.0	4.5	25
Loch Raven, 1952	0.76	4.0	5.8	15
Triadelphia Reservoir, 1952	0.92	3.8	4.4	13
Deep Creek Lake	0.53	3.5	5.4	14
Potomac River, 1954	0.47	3.0	6.3	21
Lake Waterford, 1957	0.23	0.7	3.2	6
Urieville Pond, 1958	0.23	1.0	4.4	4
Smithville Pond, 1957	0.37	1.3	3.5	5
Hughesville Pond, 1957	0.54	1.0	1.8	4

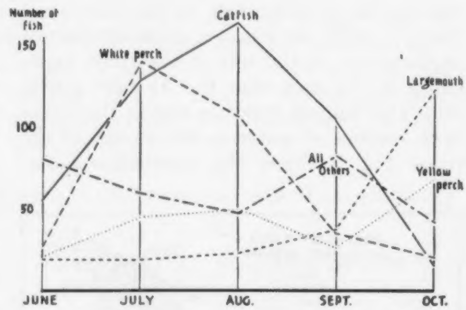

FIG. 4.—Monthly harvest of fish per 1000 hours of general fishing during 1958 in the Northeast River, Maryland.

by men, with women and children (under 15) making up 10 percent each (Table 3). This angling was done mostly by Pennsylvanians (62 percent) with people from Cecil County and Delaware accounting for only 22 and 11 percent, respectively.

The average fishing trip lasted 5.4 hours, during which the catch amounted to 1.5 fish of all species. This calculates to 0.29 fish per man hour of fishing, a decidedly low rate of catch. For comparison, the rate of catch for some other bodies of water in Maryland are given in Table 4.

There is a large variety of fish available to the Northeast angler; 20 species were recorded by the field man. Only two of these species, spot and American shad, are not year-round residents of the upper bay re-

gion, and therefore are not completely subject to Maryland management.

The catfish family, especially channel catfish, accounted for 26 percent of the fish kept. Largemouth bass, surprisingly, made up 19 percent of the catch with white and yellow perch amounting to 18 and 15 percent respectively. Studies in Maryland indicate it is unusual for bass to comprise such a large share of the catch in a mixed-species population—in this case it is partly accounted for by the relatively good fishing for this species in October. Fig. 4 shows the rate of catch of the four most important species by months. Table 3 lists the estimated total catch for the season.

The catch of fish was not evenly divided among the anglers. The 10 percent best fishing trips accounted for 46 percent of the total catch of fish, while 48 percent of the fishing trips produced no fish worth keeping.

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Salt Balance and Exchange Rate for Chincoteague Bay[1]

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ABSTRACT

Chincoteague Bay is a bar-built estuary with two inlets from the Atlantic Ocean—one at Ocean City, Maryland, and the other some 30 miles southward at Chincoteague Inlet. All available salinity data collected in the years 1951 through 1956 are utilized here to evaluate the processes which control the average monthly salinity in the bay. The major features of the salt balance are satisfactorily explained by a simple model equating the rate of change of salinity to terms involving net fresh water inflow and exchange rate through the inlets. An estimation of the exchange rate is made which indicates that approximately seven percent of the volume of the bay waters are renewed each day.

Salinity observations made in Chincoteague Bay and adjacent tidal waters in Maryland and Virginia during the years 1951 through 1956 have been reported by McGary and Sieling (1953) and by Sieling (1957). The data are not sufficient to allow a detailed investigation of the salinity balance in any given year. However, the data are adequate to compute average monthly salinities for various subdivisions of the bay, and for the entire bay, for the six years of record. These data are used here to examine the salt balance and the exchange rate for Chincoteague Bay and the adjacent Sinepuxent Bay, Assateague Bay, and Assateague Cove.

Information on the physical dimensions of the bay, the rise and fall of the tide, the freshwater inflow, and the salinity distribution is required for this discussion. Before presenting a description of the processes controlling the salt balance and estimation of the exchange rate, a brief outline of the procedure employed in processing these data will be given.

Physical Dimensions

The area included in these determinations includes Sinepuxent Bay, Chincoteague Bay, and Assateague Bay and Cove. The northern boundary of the area is at the Ocean City Inlet. The southern boundary runs from Gunboat Point on Wallops Island to Fishing Point on the south end of Assateague Island. The area of the water surface at mean low water (MLW) is 3,536 million square feet, and the volume of water at MLW is 14,494 million cubic feet. The volume of water in the area at mean tide is increased to 16,025 million cubic feet.

Tidal Information

In order to determine the appropriate tidal volume parameters, the area of the bay was subdivided into sixteen segments as shown in Fig. 1. The selection of these areas was based on the change in the High Water Interval along the length of the bay. The area, mean depth, and volume of each of these segments were determined along with the pertinent tidal information. Table 1 gives some of this information for each segment. The tidal data used in this compilation were obtained from U. S. Coast and Geodetic Survey publications and from the U. S. Army Corps of Engineers (unpublished data).

The tidal wave enters the bay through Ocean City Inlet on the north and Chincoteague Inlet on the south. The two waves travel as progressive waves toward the center of the bay, and hence time of high water

[1] Contribution No. 45 from the Chesapeake Bay Institute. This work was supported by the State of Maryland (Department of Research and Education) and the Commonwealth of Virginia (Virginia Fisheries Laboratory).

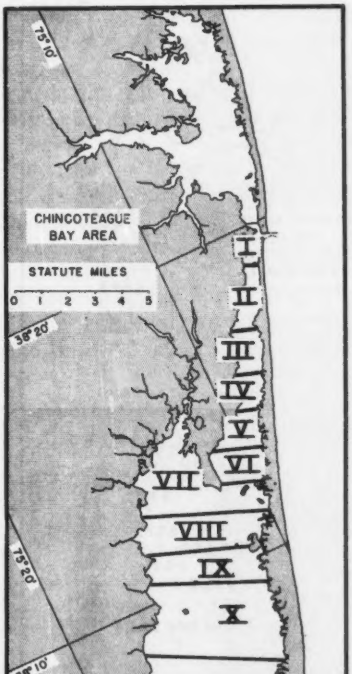

Fig. 1.—Chincoteague Bay subdivisions for tidal volume calculations.

TABLE 1.—Data on area, mean depths, and pertinent tidal information of 16 subdivisions of Chincoteague Bay.

Segment	Area	Av Depth below MLW	Volume below MLW	Volume below mean tide level	Mean tidal range	Time of H.W. after H.W. at Ocean City
	$10^6\ ft^2$	ft	$10^6\ ft^3$	$10^6\ ft^3$	ft	hrs
I	18.7	3.2	59.8	91.6	3.4	0
II	43.5	2.0	87.0	113.1	1.2	1
III	37.8	2.0	75.6	94.5	0.9	2
IV	37.8	2.0	75.6	86.9	0.7	3
V	42.6	2.0	85.2	98.0	0.5	4
VI	73.9	2.0	147.8	162.6	0.4	5
VII	242.0	3.0	726.0	750.2	0.3	6
VIII	138.2	3.4	469.9	497.5	0.4	7
IX	166.6	3.5	583.1	616.4	0.4	7
X	386.0	5.0	1930.0	2007.2	0.4	6
XI	646.0	4.6	2971.6	3100.8	0.4	5
XII	494.0	4.0	1976.0	2124.2	0.5	4
XIII	320.0	3.6	1152.0	1248.0	0.7	3
XIV	559.0	3.6	2012.4	2347.8	1.2	2
XV	164.8	7.0	1153.6	1384.3	2.7	1
XVI	164.8	6.0	988.8	1301.9	3.8	0

occurs progressively later from Ocean City towards Ricks Point, and from Chincoteague Inlet towards Ricks Point. Because of this progressive feature of the tide, the net inter-tidal volume for the bay (a value to be utilized in the discussion of exchange rate) cannot be determined by simply summing the inter-tidal volumes for each segment.

The inter-tidal volume is defined as the volume contained between the plane of low water and the plane of high water. The inter-tidal volume for each segment has been determined and is given in Table 2 in the column headed "$\Delta V(10^6 ft^3)$." Also given in this table is the ratio of the inter-tidal volume to the mean tide volume of the segment. This ratio, designated r_v, represents the fractional change in volume due to the rise and fall of the tide.

In order to determine the net inter-tidal volume for the entire bay area the height of the tide above local mean low water for each hour of the tidal cycle was multiplied by the segment area, for each of the 16 segments and for each of the 12 hours of the tidal cycle. The volume of water contained above the surface of local mean low water was thus obtained for each segment for each hour of the tidal cycle. By summing these values over the area of the bay for each hour of the tide, the volume of water contained above

TABLE 2.—Volume above local mean low water in Chincoteague Bay.

Segment	Volume below mean tide	ΔV	r_v
	$10^6\ ft^3$	$10^6\ ft^3$	
I	91.6	63.6	0.694
II	113.1	52.2	0.462
III	94.5	34.0	0.360
IV	86.9	26.4	0.304
V	98.0	21.3	0.217
VI	162.6	29.6	0.182
VII	750.2	72.6	0.097
VIII	497.5	55.3	0.111
IX	616.4	66.6	0.108
X	2007.2	193.0	0.096
XI	3100.8	258.4	0.083
XII	2124.2	247.0	0.116
XIII	1248.0	224.0	0.179
XIV	2347.8	670.8	0.286
XV	1384.3	445.0	0.321
XVI	1301.9	626.3	0.481

the surface of local MLW for the entire bay area was obtained as a function of time. A plot of the resulting data has a general sinusoidal shape, with the minimum volume in the bay occurring at about 8.40 hours after high water at Ocean City, and the maximum volume occurring at about 1.85 hours after high water at Ocean City. At the time of maximum volume approximately 2,537 million cubic feet of water occurs above the surface of local mean low water, and at the time of minimum volume approximately 720 million cubic feet occurs above the surface of local mean low water. The difference between these two volumes—that is, 1,817 million cubic feet—represents the net inter-tidal volume of the bay. The ratio of the net inter-tidal volume to the total volume of the bay is 0.113.

Salinity Data

Salinity data employed in this study were treated in two ways. First, in order to depict the characteristic horizontal distribution, observations from each of the representative series of stations were averaged for the six years of record, for three-monthly intervals. These intervals were selected to show the distribution during the period of low salinities in the bay, during the period of high salinities in the bay, and during periods

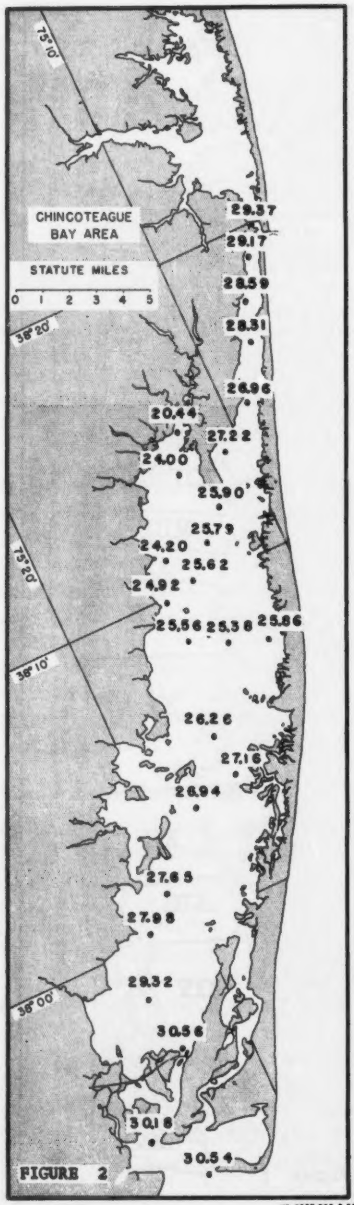

Fig. 2.—Salinities in Chincoteague Bay, February through April, 1951–1956.

intermediate in character. The salinity distribution for February through April, a period of low salinities, is shown in Fig. 2, while that for May through July, a period of increasing salinities, is shown in Fig. 3. The period of high salinities in August through October is shown in Fig. 4, while Fig. 5 gives the distribution for November through January. Surface and bottom observations, when available, were averaged since no significant vertical gradient occurred except for stations in upper Newport Bay.

For the purpose of studying the salt balance in the bay, the available salinity data were averaged for each segment shown in Fig. 1 for each month, over the six years of record. The volumes of each segment were then utilized in computing a volume mean salinity for the entire bay. The mean annual variation in salinity, thus determined, is shown graphically in Fig. 6 by the curve marked $\bar{s}$. Also shown in this figure by the curve marked s_0 is an estimate of the mean salinity of the coastal waters available for exchange with the bay waters.

Fresh Water Inflow Data

Fresh water is added to the bay by direct rainfall and by run-off from land, and is lost from the bay by evaporation. The net fresh-water inflow is an important parameter in controlling the salinity distribution. In the determination of this parameter the following data were utilized: (a) the monthly average rainfall for the six-year period at Snow Hill; (b) the monthly average rainfall for the six-year period at Ocean City; and (c) evaporation data from Salisbury and from Beltsville. These data were obtained from the published U. S. Weather Bureau Climatic Data.

The rainfall on the watershed of the bay was assumed to be given by a weighted average of the rainfall at Snow Hill and at Ocean City, with Snow Hill values being weighted by a factor of two. Similarly, the direct rainfall on the bay was obtained by weighting the values from Ocean City by a factor of two in averaging with the rainfall data from Snow Hill. The evaporation data were obtained using U. S. Weather Bureau Class-A

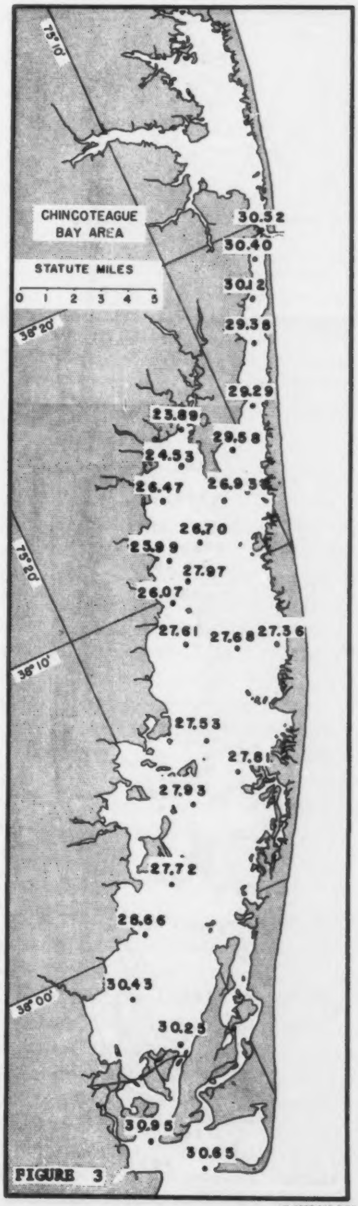

Fig. 3.—Salinities in Chincoteague Bay, May through July, 1951–1956.

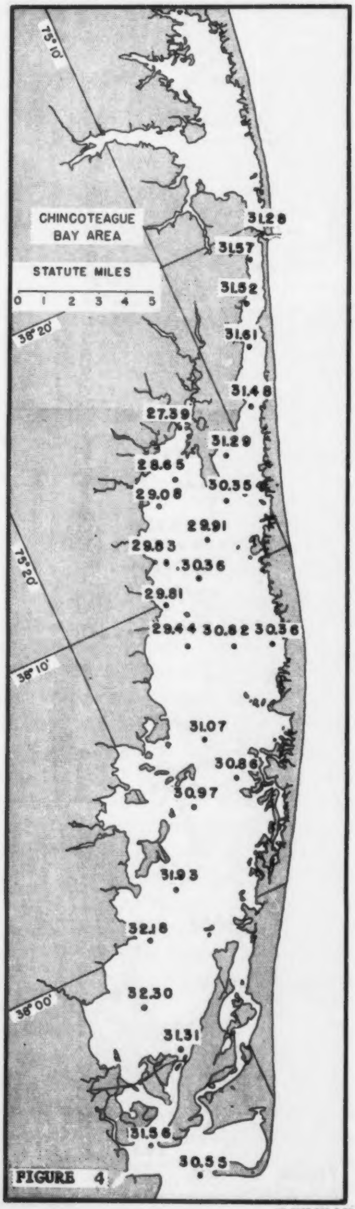

Fig. 4.—Salinities in Chincoteague Bay, August through October, 1951–1956.

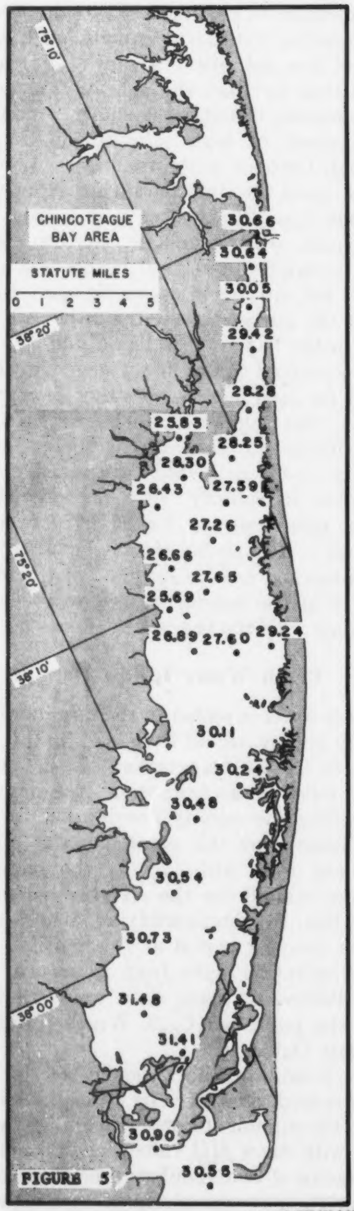

Fig. 5.—Salinities in Chincoteague Bay, November through January, 1951–1956.

type evaporation pans. Because of excessive solar heating, these pans give too high a value for evaporation. The most recent and extensive study of the appropriate correction factor to apply to the evaporation pan data is contained in Geological Survey Circular 229, entitled "Water-Loss Investigations: Volume 1—Lake Hefner Studies, Technical Report." On the basis of information from this paper, corrected monthly evaporation values were determined for the bay and the watershed surrounding the bay.

Only a part of the rain that falls on the watershed flows into the bay as run-off. The ratio of the amount of run-off to the rainfall is called the run-off factor. This factor varies throughout the year, and in any given watershed this variation is dependent to a large degree on the variation in evaporation. The functional relationship between the run-off factor and evaporation is not known in general. However, on the basis of reasonable assumptions regarding the likely variation in the run-off factor, an approximate relationship might be:

$$\eta = e^{-\beta E}$$

where η is the run-off factor, E the observed pan evaporation, and β an appropriate factor determined by the average annual value of η. It is seen that this relationship satisfies the conditions that when E becomes large, $\eta \rightarrow 0$, and when E approaches zero, η approaches unity.

In order to make the run-off into the bay directly comparable to the direct rainfall on and evaporation from the bay, the run-off factor used here has also included a correction for the difference in the area of the bay and of the watershed.

Studies of watersheds along the nearby coastal plain have indicated that the average annual run-off factor (corrected for area) should be 0.31. On this basis we can determine that

$$\eta = e^{-0.27E}$$

The monthly mean values of the rainfall, evaporation, run-off, and resulting net fresh water inflow are given in Table 3. The last column of this table is the ratio of the net fresh water inflow per day to the volume of the bay below mean tide level. During the months of June, July, August, and September, there is a net loss of water due to an excess of evaporation, while during the remainder of the year the net freshwater inflow is positive. The annual average freshwater inflow, expressed as a fraction of the volume of the bay, is 0.84×10^{-3} per day, and hence the net freshwater inflow per year is equal to 31 percent of the volume of the bay. However, the net freshwater inflow during the four-month period November through February is equal to nearly 25 percent of the volume of the bay.

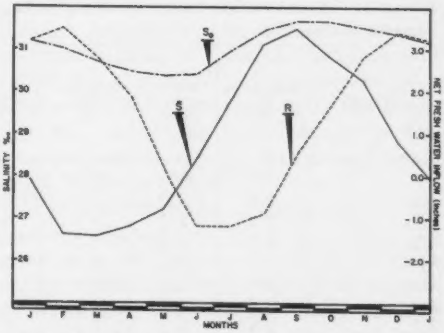

Fig. 6.—Annual variation in average salinity of Chincoteague Bay ($\bar{s}$); in salinity of ocean water at entrances to Chincoteague Bay (s_0); and in freshwater inflow to bay (R).

The Salt Balance

The salinity distribution within the bay is dependent, in a complicated manner, on the net freshwater inflow, the tidal exchange at the inlets, and the mixing by wind and tide within the embayment. The mean secular change in salt content of the bay as a whole, and also of local stations in the central portion of the bay, appears to depend primarily on the net freshwater inflow. In Fig. 6 the monthly average salinity for the bay is given together with a slightly smoothed plot of the mean monthly values of the net fresh water inflow. Smoothing of the freshwater inflow values was accomplished by taking running three-monthly means, in order to eliminate some of the irregularities resulting from the

TABLE 3.—Mean monthly values of rainfall, evaporation, run-off, and net freshwater inflow for Chincoteague Bay.

Month	Rainfall on Bay (P)	Rainfall on Watershed	Evaporation (E)	Run-off Factor	Run-off (r)	Net Freshwater Inflow R = P + r − E			
						in inches	in ft³/sec.	in 10^5 ft³/day	R′ 10^{-3} per day
	inches	*inches*	*inches*		*inches*				
Jan.	2.8	3.0	1.0	0.66	2.0	3.8	429	371	2.3
Feb.	2.4	2.7	1.1	0.51	1.4	2.7	305	263	1.6
Mar.	3.7	4.2	1.3	0.37	1.6	4.0	452	390	2.4
Apr.	3.2	3.5	2.2	0.24	0.8	1.8	207	179	1.1
May	2.4	2.8	2.9	0.20	0.6	0.1	11	10	0.1
Jun.	2.6	3.2	4.4	0.15	0.5	−1.3	−147	−127	−0.8
Jul.	2.8	3.3	5.5	0.12	0.4	−2.3	−260	−225	−1.4
Aug.	4.4	5.3	5.4	0.17	0.9	−0.1	−11	−10	−0.1
Sept.	3.0	3.7	4.5	0.27	1.0	−0.5	−57	−49	−0.3
Oct.	3.8	4.1	3.3	0.41	1.7	2.2	249	215	1.3
Nov.	3.2	3.7	2.2	0.57	2.1	3.1	350	303	1.9
Dec.	2.6	3.0	1.4	0.68	2.0	3.2	362	313	2.0

Note: R′ = Net freshwater inflow per day/volume of bay below mean tide level.

shortness of the record. The relation between these quantities will be developed below.

Flow into the bay through the inlets brings salt into the bay, and flow out of the bay through these same inlets carries salt out of the bay. The net flux of salt due to these processes is equal to the time rate of change of the total salt content of the bay. Thus, if s is the local salt concentration, V_B the volume of the bay, Q_0 the volume rate of inflow into the bay through the inlets, s_0 the salinity of these inflowing waters, Q_b the volume rate of outflow from the bay through the inlets, and s_b the salinity of these outflowing waters, then

$$\partial/\partial t \iiint_{V_B} s dV = Q_0 s_0 - Q_b s_b \quad (1)$$

The flow rates Q_0 and Q_b are pseudo-flows, in that they do not represent the total flood inflow and ebb outflow respectively; but rather Q_0 represents that part of the flood inflow which is "new" water—that is, did not flow out of the bay on the previous ebb stage; likewise, Q_b represents that part of the ebb outflow which did not enter the bay during the previous flood stage. If $\bar{s}$ represents the volume average salinity of the bay, then Equation (1) becomes

$$V_B(\partial \bar{s}/\partial t) = Q_0 s_0 - Q_b s_b \quad (2)$$

Now, since the volume of the bay is not, on the average, changing with time, the net freshwater inflow must be in balance with the net volume flow through the inlets—that is

$$Q_b = Q_0 + R \quad (3)$$

and hence

$$\partial \bar{s}/\partial t = Q_0'(s_0 - s_b) - R' s_b \quad (4)$$

where $Q_0' = Q_0/V_B$ and $R' = R/V_B$; that is, Q_0' and R' express the inflow through the inlets and the net freshwater inflow, respectively, as fractions of the volume of the bay.

The relationship given in Equation (4) is consistent with the observed variation in mean salinity and net freshwater inflow. When the latter is large, the salinity decreases with time, and when it is small or negative, the salinity increases with time.

Q_0 represents the inflow through both the Ocean City Inlet and the Chincoteague Inlet. If one of these inlets were to be closed off from the bay, or if the flow through them were to be restricted, as would be the result of the sometimes proposed barrier across the upper arm of the bay, the magnitude of this term would decrease. Since, averaged over the year, the net freshwater inflow is positive, and since some direct relationship must exist between $\bar{s}$ and s_b, it follows that averaged over the year the bay would have a lower salt concentration than at present.

Assuming that the present flow through the two inlets is about equal, the closing off of one inlet would result in lowering the average salinity by about 1.5‰.

Equation (4) could be utilized to compute Q_0', the fractional rate of inflow to the bay, if all other factors in the equation were known; conversely, it could be utilized to predict the salinity variation with time, with Q_0 and the river inflow given, provided that the relationship between the average salinity of the bay, $\bar{s}$, and salinity of the bay waters which directly exchange with the coastal waters, s_b, were known. This relationship is not known. As a first approximation, we assume that

$$s_0 - s_b = n(s_0 - \bar{s}) \tag{5}$$

where n is taken as a constant, generally less than unity. Equation (4) then becomes, since $Q_0' + R' = Q_b'$

$$\partial\bar{s}/\partial t = nQ_b'(s_0 - \bar{s}) - R's_0 \tag{6}$$

If nQ_b' and s_0, the salinity of the ocean at the inlets, are assumed constant, then the solution to Equation (6) is well known, and a predicting equation for the time variation in average salinity over the bay is obtained.

For the year as a whole, the time rate of change of salinity, $\partial\bar{s}/\partial t$, is taken as zero, since on the average the bay is neither getting fresher nor saltier. Under these circumstances we have:

$$nQ_b' = R's_0/(s_0 - \bar{s}) \tag{7}$$

This equation also applies at the time of the March minimum in $\bar{s}$ and also the time of the September maximum in salinity (see Fig. 6). The average value of $\bar{s}$ over the year is 28.80‰, and that of s_0 is 31.06‰. The net freshwater inflow, expressed as a fraction of the volume of the bay, averaged over the year, is 0.84×10^{-3} per day. Equation (7) then gives for nQ_b' a value of 1.2×10^{-2} per day. The corresponding values of s_0, $\bar{s}$, and R' for March give a value for nQ_b' of 1.3×10^{-2} per day, and those for September a value of 2.9×10^{-2} per day.

More generally, Equation (6) may be solved for nQ_b'; thus:

$$nQ_b' = (\partial\bar{s}/\partial t + R's_0)/(s_0 - \bar{s}) \tag{8}$$

The period of salinity increase from June through August may be utilized to obtain an estimate of $\partial\bar{s}/\partial t$. Using the corresponding values of $\bar{s}$, s_0, and R' in Equation (8) gives a value of 1.6×10^{-2} per day for the quantity nQ_b'. A similar computation for the period of decreasing salinities gives a value of 2.9×10^{-2} per day.

It is clear that the quantity nQ_b' is not constant throughout the year. Also, the salinity at the inlets, s_0, shows a slight annual variation. However, it is of interest to investigate how well the mean monthly salinity of the bay can be predicted from the simplified solution of Equation (6) with the approximation that nQ_b' and s_0 are constant.

Using a mean value of 1.7×10^{-2} per day for nQ_b', and 31.06‰ for s_0, the integral solution to Equation (6) was employed in computing the mean monthly salinities for the bay. Fig. 7 gives a comparison of the observed and computed values of $\bar{s}$, the monthly average salinity for the bay. The departure of the computed curve from the observed curve is in the direction to be expected to result from the assumptions employed. In the late winter and spring months, the exchange rate and hence nQ_b' is evidently less than average, and hence the freshwater actually accumulates in the bay to a greater degree than would be expected, producing observed salinities lower than computed. Also, in spring and early summer, the salinity of the ocean water at the entrances to the bay is less than average, while in September

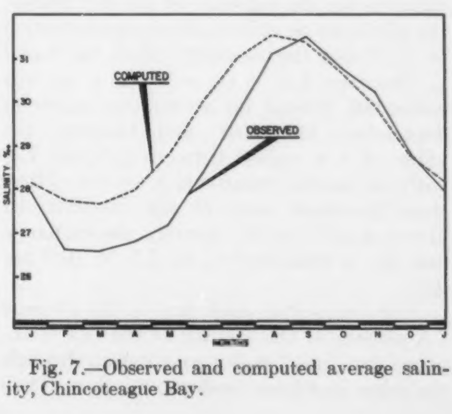

Fig. 7.—Observed and computed average salinity, Chincoteague Bay.

through October it is greater than average. This departure would also contribute to the differences in the curves in Fig. 7.

Even with these differences, the simple model used does appear to explain the major features of the annual salinity variation.

The Renewal Time

The inflow of fresh water and the exchange through the inlets lead to a replacement of water within the bay. This replacement results in the flushing from the bay of any water-borne contaminant, at a rate determined by the rate of renewal of the water.

Consider that the water in the bay was composed of individual particles, and that these small particles present at a given time were in some way "tagged." Each day a certain fraction of these "tagged" particles would be lost from the bay, to be replaced by new, "untagged" particles. The fraction of tagged particles removed each day is the same as the fraction of bay water which flows out of the inlets and does not return with ensuing flood tides, and hence the fractional rate of removal of "tagged" particles is equal to the quantity $Q_b' = Q_b/V_b$.

In order to compute Q_b' from Equation (6), an estimate of the fraction n must be obtained. Note that in general the difference $(s_0 - s_b)$ will be less than the difference $(s_0 - \bar{s})$, and n will be less than unity. If, as is frequently done, n is taken as 1.0—that is, s_b is identified with s_0—then the exchange rate, Q_b', will be underestimated.

In the present situation the monthly mean salinities for the segments of the bay nearest the inlets can be utilized as an approximation of s_b. Using the monthly values for $\bar{s}$ and s_0, the ratio $1/n = (s_0 - \bar{s})/(s_0 - s_b)$ was estimated. Except for anomalous values in September, December, and January, the value of $1/n$ varied between 2.5 and 7.3, with an annual mean value of 4.4. Thus, since the mean value of nQ_b', as obtained above, was 1.7×10^{-2} per day, the exchange rate Q_b' is estimated to be 7.5×10^{-2} per day.

This means that each day on the average 7.5 percent of the volume of the bay is replaced by "new" water contributed through the inlets and from freshwater inflow. Thus 7.5 percent of the "tagged" particles discussed above would be removed each day.

Theoretically, the water in the bay is never completely renewed. The *renewal time* then refers to the time required to replace a certain percentage of the water of the bay. Frequent use is made of the 50 percent renewal time, or the time interval required to replace one-half of the water present at a given instant. Another measure is the 99 percent renewal time, which is the time interval required to replace 99 percent of the water present at any given instant.

If we designate the number of "tagged" particles present at any time by C, and the number which were originally present at time t_0 by C_0, then if a certain fraction γ of these particles are "flushed" from the bay each day, we have

$$dC/C = -\gamma dt \tag{9}$$

where t is time in days. Or

$$\ln C/C_0 = -\gamma(t - t_0) \tag{10}$$

The 50 percent renewal time is the time required to replace half the water present. This occurs when $C/C_0 = 0.5$, or $C_0/C = 2.0$. Hence,

$$t_{1/2} = 0.693/\gamma \tag{11}$$

When 99 percent of the bay volume is flushed, then $C/C_0 = 0.01$, and $C/C_0 = 100$.

$$t_{0.99} = 4.605/\gamma \tag{12}$$

From above, our estimate of γ is 0.075. Then

$$t_{1/2} = 0.693/0.075 = 9.3 \text{ days},$$

and

$$t_{0.99} = 4.605/0.075 = 62 \text{ days}.$$

In the section on tides in the bay it was determined that the ratio of the net intertidal volume to the total volume of the bay is equal to 0.113, which we will here designate as $\bar{r}_v$. This means that during each tidal cycle there occurs a cyclic change in the volume of the bay, due to tidal flow through the inlets, of 11.3 percent of the volume of the bay. Only a fraction of the flow in through the inlets on a given flood represents new water, the major portion of

the flood flow being water which flowed out through inlets on the previous ebb. If we designate that fraction of the flood flow which is "new" water as r_n, then the exchange ratio is equal to $r_n r_v$.

On the basis of the salt balance, γ was determined above to be 0.075 per day. Since r_v is 0.113 per tidal cycle, then r_n must be approximately 0.34. That is, about 34 percent of the water that enters the bay each tidal cycle is "new" water. This estimate is consistent with visual observations that an appreciable fraction of the ebbing flow through Ocean City Inlet is swept southward with the prevailing long shore current.

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Preliminary Report on Attracting Fish by Oyster-Shell Plantings in Chincoteague Bay, Maryland[1]

John Arve

ABSTRACT

Oyster-shell plantings were made on formerly productive bottom to determine the practicability of securing an oyster set in this area and to test the hypothesis that the availability of game fish could be improved by artificially modifying the habitat in Chincoteague Bay, Maryland. Fish populations were trapped over planted and unplanted control areas with the same effort from August to November in 1958 and 1959. Fourteen species of saltwater fish were recorded in the planted and control areas, of which the black sea bass, *Centropristes striatus*, was the dominant species.

The planted areas yielded about three times as many fish as the controls during the two years. Black sea bass numbers were much greater on planted areas than on control areas. The planted area also produced more species than the unplanted area. More fish were caught over both planted and control bottoms during 1959 than in 1958, due partially to improved trap design. There is some evidence of improvement in the availability of fish over a planted area that has aged for a year. It is concluded that oyster-shell plantings significantly concentrated and increased numbers of fish over restricted areas, when compared to unplanted areas.

Introduction

Basis for Study

The present project was designed to test the hypothesis that fishing can be improved by artificially changing the bottom of tidewater habitats. Observations by local commercial and a few sport fishermen and oystermen in Chincoteague Bay, Worcester County, Maryland, have indicated that oyster-shell plantings were followed by increased catches of certain species of fish when compared to catches on unplanted bottoms. Accordingly, the present experiment, part of an effort to determine the practicability of securing an oyster set in the area, was undertaken with these objectives: (a) to determine by introducing oyster shells on once productive bottoms whether fish populations were more available or abundant over planted versus unplanted bottoms; (b) to ascertain the seasonal availability and movements of fish during the various seasons between planted and unplanted areas; and (c) to explore means of improving sport fishing in the bay.

Acknowledgments

Appreciation is extended to Mr. Fred Sieling, biologist-in-charge of the Public Landing Station of the Maryland Department of Research and Education on Chincoteague Bay for his aid, assistance and encouragement in the initiation and direction of this project; to Mr. Roland Pusey, summer aide, who assisted in the design of traps and in the field work; and to Dr. R. Mansueti, senior fishery biologist, Chesapeake Biological Laboratory of the Maryland Department of Research and Education, for his suggestions and criticism of the manuscript.

Description of the Area and Methods

Geography and Hydrography

The experiment was conducted in the Maryland part of Chincoteague Bay, a long, comparatively narrow and shallow body of water with inlets at the north and south ends, and separated from the Atlantic

[1] Contribution No. 137, Maryland Department of Research and Education, Solomons, Maryland.

Ocean by Assateague Island. The average depth of the entire bay is four feet, but throughout the experimental area (Fig. 1) the average depth is seven to eight feet. Tidal amplitude in this portion is approximately one foot. The average salinity over a six-year period varied from 30.4 in the autumn to 25.4 ppt in spring. Average temperatures over this same period were from 24.5°C in summer to 5.5° in the winter. The bottom at the study area was an old natural oyster bar which had only a very light covering of silt (see Stout, 1953), and in general was representative of much of Chincoteague Bay. Further hydrographic details of the area are given by Sieling (1955:2, 4 and 5).

Selection of Study Area

This project was carried out in conjunction with a separate experiment involving the production of seed oysters. The general sites of planted, or treatment, areas and unplanted, or control, areas were selected because of their ability to support sport fishing in past years. They were located on the outer extremities of an old silted-over oyster bar, where the bottom was rigid enough to prevent planted oyster shells from settling below the soft layer of mud. This portion of the bay has an extensive area of ecologically uniform bottoms and was therefore considered suitable for establishing both experimental and control plots.

Three plots, each about two acres in area, approximately 2000 feet apart, and roughly equidistant from one another, were marked out with stakes at each corner as indicated on the chart of the area (Fig. 1). Plot 1 became the principal planted area, herein cited as P-1. Another plot, which was the principal unplanted area, or Control 1, herein cited as C-1, was staked off about 2000 feet to the southwest of P-1. Another unplanted area, Control 2, or C-2 was set up in 1958 to determine an estimate of variation between untreated areas. In 1959, C-2 was planted and became P-2 to test any differences in catch that might arise between the 1958 planted bar and the 1959 planted bar due to aging. C-1 served as a control for P-1 and P-2 in 1959. About 2000 bushels of oyster shells were planted per acre. These

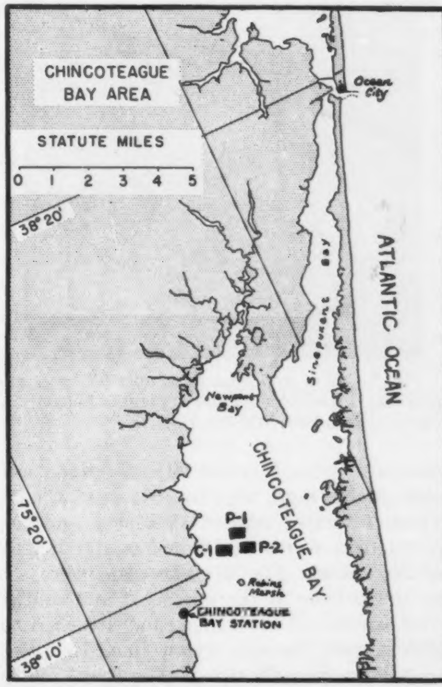

Fig. 1.—Location of oyster-shell planted plots (P-1 and P-2) and control plot (C-1) in Chincoteague Bay, Maryland.

were obtained from oyster shucking plants and were planted as oyster cultch by the "broadcasting" technique. The method used consisted of holding a barge at low speed in a circular path while the shells are dispersed from the vessel with pitch forks. The shells were scattered to avoid the creation of clumps. After the shells were planted skin-divers checked and reported them to be uniformly scattered over the bottom. Examination further indicated that the planted bottom averaged about three shells deep.

Method of Fish Population Check

The systematic capture and release of individuals over the test areas was conducted with wire traps (Fig. 2) that caught the fish alive and unharmed. The traps, which were three feet long, two feet high, and two feet wide, consisted of a framework made with ¼ inch steel rods welded at the corners, and wrapped with 20-gauge one-

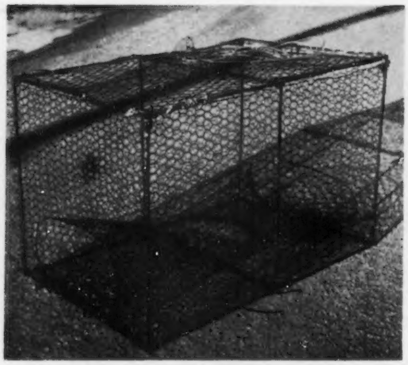

Fig. 2.—Wire trap used to sample fish over experimental shell-planted and unplanted bottoms in Chincoteague Bay, Maryland.

inch mesh wire. Funnels, 22 inches wide and eight inches high, were located at each end. These extended inward 12 inches and tapered to a width of 18 inches and height of 2½ inches (Fig. 2). The traps were set on the bottom at the northeast and southwest corners of each area, and attached to stakes with ⅛-inch nylon line. In 1958, they were periodically and systematically interchanged between planted and control areas in order to eliminate the bias that might be caused by a superior-fishing trap. During 1959, the construction of traps was improved so that trap design may have caused some of the substantial increase in catches. After the traps were set in March

Table 1.—List of fish recorded in traps and ranked according to abundance over experimental and control areas in the Chincoteague shell planting study.

Local Name	Recommended Common Name	Scientific Name
Bass	Black Sea Bass	*Centropristes striatus*
Perch	White Perch	*Roccus americanus*
Flounder	Summer Flounder	*Paralichthys dentatus*
Puffer	Northern Puffer	*Sphaeroides maculatus*
Spot	Spot	*Leiostomus xanthurus*
Toad	Toadfish	*Opsanus tau*
Pin	Pinfish	*Lagodon rhomboides*
Blue	Bluefish	*Pomatomus saltatrix*
Menhaden	Atlantic Menhaden	*Brevoortia tyrannus*
Eel	American Eel	*Anguilla rostrata*
Tautog	Tautog	*Tautoga onitis*
Stingray	Southern Stingray	*Dasyatis americana*
Butterfish	Butterfish	*Poronotus triacanthus*
Butterfly	Spotfin Butterflyfish	*Chaetodon ocellatus*

1959 they were not relocated or replaced during the experiment. During 1959, traps on the planted areas were corroded, and holes developed large enough for some escapage. Corrosion in traps on the control area was minimal and holes were absent.

Sampling Procedure

Traps were checked and reset every Monday, Wednesday and Friday from July to November 1958, except when adverse weather temporarily interrupted the schedule. Effort did not vary between the two experimental areas during the study. The schedule was repeated during 1959, but the span of sampling ranged from April to November. Also, a more seaworthy boat allowed better adherence to the sampling schedule, although no more effort was extended for a comparable period than in 1958. Only the period from August to November was used in comparing the catches between the two years.

Tagging

A limited tagging program with black sea bass was undertaken to determine: (a) the degree and frequency of movement between areas; (b) the persistence of tagged fish over the study areas during the span of the six months; and (c) whether repetitive catches of individual fish would occur. Monel metal opercular tags, each numbered and identified with the Maryland Department of Research and Education, Solomons, Maryland, were applied. The tag number, the place of capture and release, length, and sex, were recorded.

Results

Species of Fish

Table 1 lists all species of fishes recorded in the traps. Fig. 3 shows the monthly percentage composition of the total catch by year for P-1 and C-1. Although other species figured prominently in the study, the black sea bass constituted over one-half of all fish caught. Some details concerning the biology of this species are given later in this paper.

Planted (P-1) Versus Control (C-1) Bottom Catches

P-1 and C-1 are regarded as a pair. Table 2 and Fig. 3 give the principal results of the experiment. Of the total number of fish caught during 1958, 89 percent were caught on the planted area. During 1959, 66 percent were caught on the planted area. The planted area also produced more species than the unplanted area.

Black sea bass dominated the catches on both planted and unplanted areas. Since their numbers were much greater than for all other species combined, and because the catches were well-distributed over the four-month trapping period that was compared for each year, the experiment in a sense is a test of the response of this species to planted versus unplanted bottoms. Table 2 shows that the difference in numbers on the two bottoms is very great for comparable periods (i.e., August through November, 1958 and 1959). Chi square analysis shows that these differences are highly significant far beyond the one percent level.

An important difference in the numbers of black sea bass attracted over the two experimental bottoms is evident between 1958 and 1959. Twice as many fish were taken with the same effort in 1959 as in 1958. The control bottom produced four times as many black sea bass in 1959 as in 1958. Percentage-wise, the control area improved its production twice as much as the planted area. Thus, differences in catches on both planted and on control bottoms between years are very great; chi square tests show them to be highly significant far beyond the one percent level. Since equal effort was maintained between years during the trapping program, improved wire trap design and general increase in fish abundance

Table 2.—Comparison of the number of fish caught by species over oyster cultch planted (P-1) versus unplanted (control) bottoms (C-1) by month during 1958 and 1959.

	Plots[1]	1958				1958 Total	Percent of all	Plots	1959								1959 Total	Percent of all	Grand Total	Percent of Grand Total
		Aug	Sept	Oct	Nov				Apr	May	Jun	Jul	Aug	Sept	Oct	Nov				
Black Sea Bass	P-1	55	33	1	4	93	80.9	P-1	—	—	—	4	87	62	29	13	195	68.4	288	72.0
	C-1	9	5	8	—	22	19.1	C-1	—	—	—	1	11	9	36	33	90	31.6	112	28.0
White Perch	P-1	32	11	1	—	44	100	P-1	—	—	2	3	24	5	—	—	34	89.5	78	95.1
	C-1	—	—	—	—	—	—	C-1	—	—	—	1	3	—	—	—	4	10.5	4	4.9
Pinfish	P-1	34	35	—	—	69	98.6	P-1	—	—	—	—	—	—	—	—	—	—	69	98.6
	C-1	—	1	—	—	1	0.4	C-1	—	—	—	—	—	—	—	—	—	—	1	0.4
Summer Flounder	P-1	1	2	1	—	4	80.0	P-1	—	—	—	—	6	—	2	—	8	23.5	12	30.8
	C-1	1	—	—	—	1	20.0	C-1	—	—	—	—	17	9	—	—	26	76.5	27	69.2
Northern Puffer	P-1	—	—	—	—	—	—	P-1	1	10	31	—	—	—	—	—	42	71.2	42	71.2
	C-1	—	—	—	—	—	—	C-1	—	—	9	—	—	—	—	—	9	28.8	9	28.8
Spot	P-1	1	—	—	—	1	100	P-1	—	—	—	2	6	1	—	—	9	34.6	10	37.0
	C-1	—	—	—	—	—	—	C-1	—	—	—	3	9	5	—	—	17	65.4	17	63.0
Toadfish	P-1	2	1	—	—	3	75.0	P-1	—	—	—	2	6	1	—	—	9	45.0	12	50.0
	C-1	1	—	—	—	1	25.0	C-1	—	—	2	1	6	2	—	—	11	55.0	12	50.0
All Other Species[2]	P-1	2	1	—	1	4	80.0	P-1	—	—	2	1	5	—	1	—	9	81.8	13	81.2
	C-1	—	—	—	—	—	20.0	C-1	—	—	—	—	—	1	1	—	2	18.2	2	18.8
Total	P-1	127	83	3	5	218	89.3	P-1	1	10	35	12	134	69	32	13	306	65.8	524	73.9
	C-1	10	6	9	—	25	10.7	C-1	—	—	11	6	46	26	37	33	159	34.2	184	26.1
Grand Total		137	89	12	5	243			1	10	46	18	180	95	69	46	465		708	

[1] Plots are as follows: P-1 = Planted area one; C-1 = Control or unplanted area one.

[2] Other species above and on P-2 include: bluefish (6, all in P-1); American eel (6 in C-1 and P-2); butterfish (4, all in P-1); menhaden (1 in P-2); tautog (1 in P-1); butterflyfish (1 in P-1); stingray (1 in P-1).

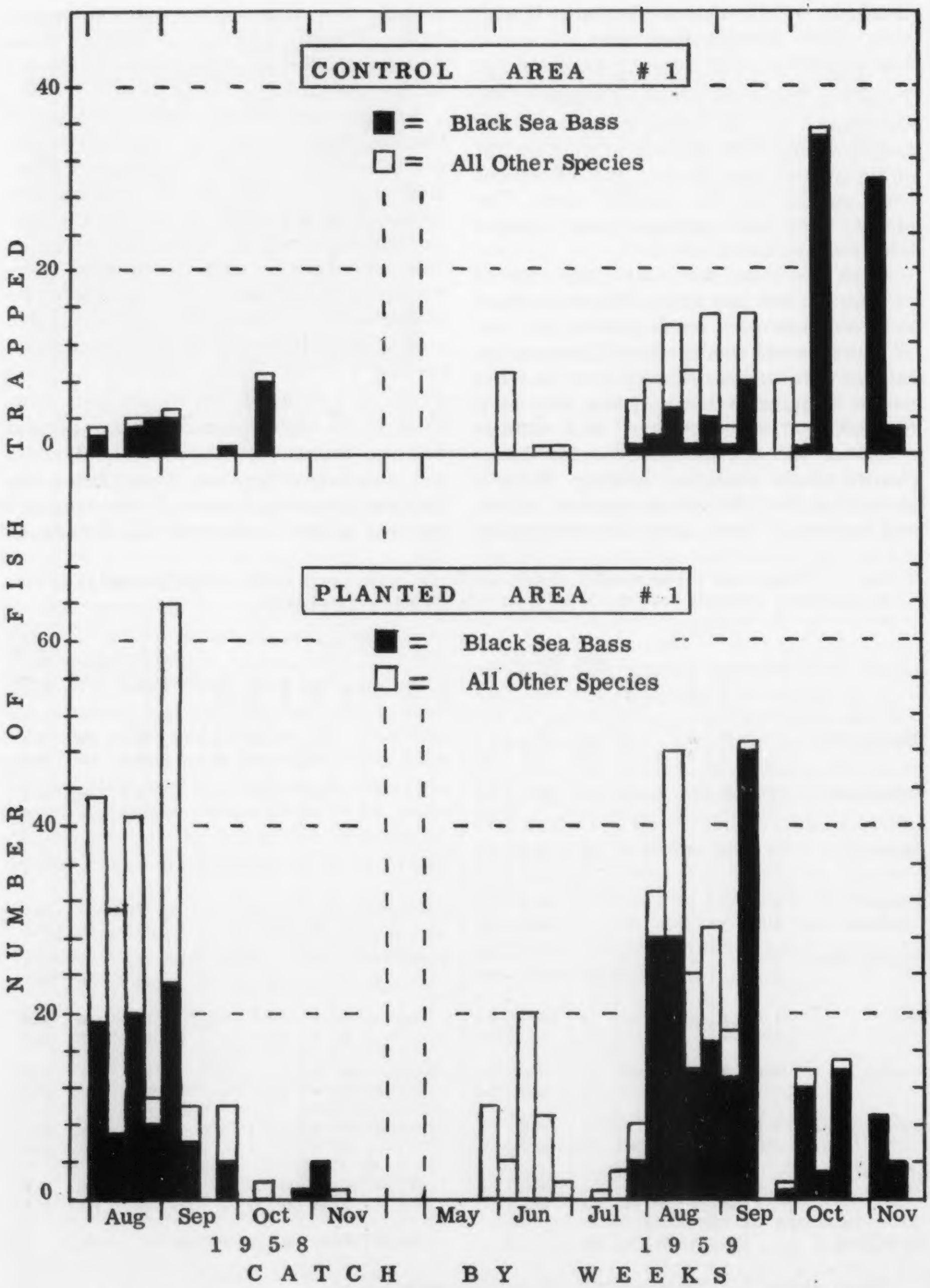

Fig. 3.—Catches of fish over planted and control bottoms during 1958 and 1959 in Chincoteague Bay, Maryland.

TABLE 3.—Number of fish caught by species over a single plot that served as an unplanted control (C-2) in 1958 and as an oyster cultch planted bottom (P-2) in 1959. See text for comparisons.

	Plot	1958				1958 Total	Plot	1959				1959 Total
		Aug	Sept	Oct	Nov			Aug	Sep	Oct	Nov	
Black Sea Bass	C-2	10	11	14	—	35	P-2	21	11	8	5	45
White Perch	C-2	—	—	—	—	—	P-2	1	—	—	—	1
Pinfish	C-2	—	1	—	—	1	P-2	—	—	—	—	—
Summer Flounder	C-2	1	1	—	—	2	P-2	21	3	1	—	25
Northern Puffer	C-2	—	—	1	—	1	P-2	—	—	—	—	—
Spot	C-2	—	—	—	—	—	P-2	2	2	—	—	4
Toadfish	C-2	—	—	—	—	—	P-2	3	2	—	—	5
All Other Species	C-2	1	—	—	—	1	P-2	—	—	3	—	3
Total	C-2	12	13	15	—	40	P-2	48	18	12	5	83

probably account for a large part of the difference.

When the data are examined for total numbers of all species combined, it is evident that in general more individuals were trapped on the planted area than on the control bottoms. Table 2 indicates, in spite of limited quantitative evidence, that white perch, pinfish, and northern puffer occurred in greater numbers over planted bottoms. Several species, especially the summer flounder, spot and toadfish, reacted differently; the first two species were more abundant on control bottoms, while the latter species showed relatively little preference for the different plots. The small numbers of the last-named species make any interpretation unreliable. All other species given in Table 1 occurred so infrequently that they were lumped together. When the data are examined in detail for some of these species, especially the pinfish and northern puffer, it is evident that some of the catches are limited to a few months and occasionally to a few trapping days.

VARIATION BETWEEN CONTROL AREAS IN 1958

Catch data for C-1 and C-2 in 1958 are summarized in Tables 2 and 3. They indicate that while catches over C-2 were somewhat greater than those over C-1, a chi square test indicates that the difference is non-significant. Thus, the variation between the two areas, when the data of each is combined for the four months, may be due to sampling error.

VARIATION BETWEEN PLANTED AREAS IN 1959

Catch data for P-1 and P-2 in 1959 are summarize in Tables 2 an 3. They indicate that P-1 produced over four times as many black sea bass as did P-2 in 1959, and about one and one-half times as many of the remaining species of fish as did P-2 in 1959. When the two categories are combined it amounted to a 3 to 1 improvement. The evidence suggests that a second-summer planting is superior to a first-summer planting.

COMPARISON OF P-2 WITH C-1

Catch data for P-2, which are summarized in Table 3, were compared in 1959 with C-1 which served as a control for both P-1 and P-2. More black sea bass were caught on the control areas than on the planted bars. An examination of the monthly catches indicates that more bass were taken on planted than on unplanted bottoms in August and September, but that in October and November, the trend is significantly reversed. This monthly trend can also be seen in the P-1 catches in October and November. A partial reason for this change may be due to losses through holes in the wire of traps that had corroded on both P-1 and P-2 in 1959.

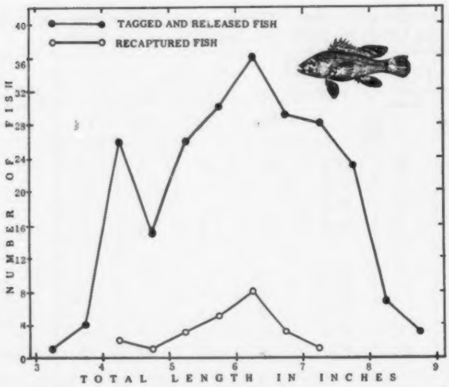

Fig. 4.—Comparison of lengths, at tagging, of released black sea bass, *Centropristes striatus*, with recaptured individuals taken alive in wire traps during the experiment, June to August 1959, in Chincoteague Bay, Maryland.

Movements of Black Sea Bass on Planted and Unplanted Bottoms

A total of 250 black sea bass were tagged during the 1959 season. Of these, 24 were recaptured once, nine taken twice, two were taken a third time, and one was recaptured four times. Practically all of the recaptures took place on the plot of initial capture and tagging. Since those fish that had been recaptured were seldom free longer than two weeks, growth data for these fish were not obtained. The limited tagging indicated virtually no movement between experimental plots, although the span of recaptures was three months. Repetitive catches of individual fish were not quantitative enough for growth rate studies. Fig. 4 shows that the group of recaptured bass is probably a random sample of the tagged and released fish.

Discussion and Conclusions

By planting shells as oyster cultch at appropriate depths over relatively barren bottoms, it was hypothesized that new, more extensive natural habitats would be created for many kinds of encrusting organisms, various bottom invertebrates, plankton, small fish, and vegetation. Thus, better feeding grounds for larger species of game and food fishes would result. Although it was recognized that such habitat changes can increase the carrying capacity of the bottom, either temporarily or permanently, any increase in the catches of fish early in the experiment would result from a concentration and redistribution of existing fish populations. Marked changes in relative abundance on both planted and unplanted bottoms between years were probably due to dominant year-classes or increased immigration.

Evidence presented in this study demonstrates that a planted bottom in general will increase the availability of certain species of fish to a significant degree over that of an unplanted bottom. It shows that the variety of species is greater than on a control bottom. The data also show that some species are unaffected. Many factors can effect an increase in catches. Variation within the catches occurred during each year. The factors affecting periodic differences in catches in the experiment are not clear. The characteristic movements and behavior of each species of fish in response to various stimuli also may account for the differences. Rainfall and wind, however, are known to affect the habitat and behavior of fish. During heavy precipitation, for example, the salinity may drop abruptly, due to the high dilution factor in a shallow body of water (Sieling, 1958:15–16, and Pritchard, 1960:51). The freshening effect may force marine fish to seek a higher salinity gradient. Wind action characteristically causes high turbidity in this shallow bay where much of the bottom and many old natural oyster bars are covered with mud (Sieling, 1954:2–3). This condition might interfere with sight and smell and restrict movements of fish.

Little evidence is available to show *how* and *why* a planted bottom will attract more individuals and a greater variety of fish than an unplanted bottom, except that which can be inferred indirectly from examination of shell plantings during oyster-culture operations. Thus, it is obvious that a new substrate is provided for the colonization of a mixture of organisms that resembles an oyster bar community. An in-

crease in the potential food supply serves to concentrate semi- or fully predaceous fishes without really increasing the supply of fish. This condition suggests that the carrying capacity has been indirectly increased by the presence of greater surface area which soon becomes inhabited by a wide variety of benthic animals and plants. The improvement of the 1959 catches of P-1 in its second year over P-2 in its first year suggests that a planted area that has aged can improve in its ability to attract fish.

The preliminary results of this study suggest that widespread shell plantings can improve the potential angling harvest of an estuary. Little angling takes place in Chincoteague Bay compared to the effort in comparable areas in Chesapeake Bay and off Ocean City, Maryland (see Sieling, 1960:14, and Covel, 1959:9–10). There is some evidence to be gleaned from commercial catch records of fish taken during the past half-century from Chincoteague Bay that recent fish populations are much less available than in the past (Sieling, 1960:11–12). This decrease in availability may be due to the loss in carrying capacity of the bay when the extensive oyster beds were depleted (Sieling, 1960:4–5). The latter condition can only be improved by artificially rebuilding the bars.

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Notes and Comments

Supplemental Survey of Soft-Shelled Clam Bottoms in Tidewater Somerset County, Maryland[1]

ABSTRACT

A second survey of populations of soft-shelled clams, *Mya arenaria*, in Somerset County, Maryland, was made during 25 August to 2 September 1959. Sixty-five areas were sampled by means of a commercial hydraulic clam dredge. Data for market and submarket clams is given in terms of bushels per acre in each area sampled. Analysis of results did not reveal any commercial quantities of clams. Factors limiting the population of soft-shelled clams in this area are not definitely known.

INTRODUCTION

The results of an exploratory survey of inshore tidewater bottoms of Somerset County conducted by the Maryland Department of Research and Education during the period 22 October to 11 December 1957 were reported by Manning and Pfitzenmeyer (1958). The primary objective of that survey was to determine the presence of commercially important quantities of soft-shelled clams, *Mya arenaria*. Population densities were found to reach commercial levels in only a few limited areas. Considerable quantities of clam shells observed at a number of sampling stations suggested that commercial populations of clams may have existed in the region in recent years. The advisability of continued observations was indicated. Accordingly, a supplemental survey was undertaken during the period 25 August to 2 September 1959 to observe what changes had occurred in the soft-shelled clam population during the two years following the original survey. The cooperation of the Maryland Department of Tidewater Fisheries is gratefully acknowledged and especially that of Inspectors Ellsworth Hoffman, Walton Webster and Roland Lankford.

METHODS

The hydraulic clam dredge equipped with a fine-mesh conveyor belt, which retains clams greater than 0.5 inches in length, and described by Manning (1957), was used throughout the survey. Areas where bottom type and stablility appeared to favor the species were selected for sampling. At each of 65 sampling stations (Fig. 1) a 20-square-foot sample was obtained. The marketable clams (shell length at least 2 inches), and submarketable clams in each sample were counted. Numerical data were converted to terms of bushels per acre, actual or potential, by means of empirical factors.

RESULTS

In order for a clam dredger to operate commercially, an average of 50 bushels per acre must be available. The quantity of clams found on this survey did not reach this figure in any area sampled. Marketable clams were found in 7 of the 65 samples, with a range of 3 to 11 bushels per acre. The highest yield per acre was found at the mouth of Teague Creek in the Manokin River. The juvenile clams (under 2 inches in length) upon which the potential crop was estimated, are a result of the 1958 set. They were found in 22 of the 65 samples and varied from 3 to 46 bushels per acre. If this entire year class survived, to be harvested in 1960, the production would not approach the yield necessary for commercial operation. A summary of the results found at each sampling station is given in Table 1.

DISCUSSION

The abundance of recent juvenile soft-shelled clam boxes found in many areas suggests the presence of a spawning stock of clams with a potential to produce an annual set of commercial quantity. Therefore, factors other than insufficient spawning stock are thought to control the population density. The relatively high salinities and mean summer temperatures of this area may be favorable to certain predaceous organisms not found in certain upper Chesapeake Bay regions where populations of soft-shelled clams are very abundant. Severe wave action on the inshore bottoms may be another decimating factor. Sizable populations of clams have been reported to occur in shallow and deep water beyond the range (3 to 10 feet) of the hydraulic clam dredge. To theorize further on the causes of this atypical distribution would require additional research. Evidence gathered from this survey points out that there does not at the present, or will not in the foreseeable future, exist in Somerset County waters a sufficient population of soft-shelled clams to support a commercial fishery.

SUMMARY

A supplemental survey of inshore tidewater bottoms of Somerset County was conducted from 25 August to 2 September 1959. Samples taken in 65 areas by means of a hydraulic clam dredge did not reveal any commercial quantities of soft-shelled clams. Factors other than insufficient brood

[1] Contribution No. 138, Maryland Department of Research and Education, Solomons, Maryland.

TABLE 1.—Results of soft-shelled clam bottom survey, Somerset County.

Station	Water Depth (Ft.)	Bottom Type and Vegetation	Oysters in Sample	Market Clams Bu./Acre	Potential Crop[1] Bu./Acre
1	8	Very soft mud. No vegetation.	0	0	0
2	4	Sandy gravel. No vegetation.	0	0	3
3	5	Loose sand. No vegetation.	1	0	6
4	4	Loose sand. No vegetation.	0	0	3
5	4	Loose sand. No vegetation.	0	0	0
6	4	Hard clayey sand. Trace of widgeon grass (*Ruppia maritima*)	0	0	0
7	5	Hard clayey sand. No vegetation.	0	0	0
8	5	Sand, shell. No vegetation.	0	0	0
9	4	Muddy sand, shell. Trace of widgeon grass.	0	0	3
10	5	Muddy sand, shell. No vegetation.	0	0	0
11	3	Sandy mud, shell mixed. No vegetation.	0	0	3
12	4	Muddy sand. Trace of widgeon grass and eel grass (*Zostera marina*).	0	3	9
13	4	Sand over clay. No vegetation.	0	0	0
14	4	Muddy sand over clay. No vegetation.	0	0	0
15	4	Loose sand over sandy mud. Trace of widgeon grass.	0	0	0
16	6	Clayey sand. Widgeon grass abundant in spots.	0	0	3
17	5	Clayey sand. Eel grass and widgeon grass abundant in spots.	0	3	11
18	5	Sand over sandy clay. Trace eel grass and widgeon grass.	0	6	20
19	3	Soft mud. Trace of unidentified vegetation.	0	0	0
20	3	Sandy mud. No vegetation.	0	0	0
21	4	Clayey sand. No vegetation.	0	0	0
22	4	Clayey sand. No vegetation.	0	0	0
23	5	Sandy mud. Eel grass sparse.	1	11	27
24	3	Clayey sand. No vegetation.	0	0	0
25	5	Clayey sand. Trace of eel grass.	0	0	9
26	5	Sand over fibrous peat. No vegetation.	0	0	0
27	4	Sandy clay over fibrous peat. No vegetation.	0	0	0
28	5	Sandy clay. Widgeon grass and eel grass sparse.	0	0	14
29	3	Soft clay over fibrous peat. No vegetation.	0	0	0
30	4	Firm sandy mud. Dense growth of widgeon grass.	0	0	8
31	3	Clay over fibrous peat. No vegetation.	0	0	0
32	4	Clay over fibrous peat. Trace of widgeon grass.	0	0	0
33	4	Sandy clay over fibrous peat. No vegetation.	0	0	3
34	4	Sandy mud over fibrous peat. No vegetation.	0	0	0
35	6	Hard sandy mud. Widgeon grass very abundant.	0	0	0
36	5	Hard sandy mud. Widgeon grass very abundant.	0	0	0
37	4	Hard sand. No vegetation.	0	0	0
38	4	Hard sand. No vegetation.	0	0	0
39	5	Hard sand. No vegetation.	0	0	3
40	4	Hard clayey sand. No vegetation.	0	0	0
41	7	Hard clayey sand. No vegetation.	0	0	0
42	5	Sandy mud over clay. Trace of eel grass.	0	0	0
43	7	Sandy mud. Trace of eel grass.	0	8	9
44	6	Muddy sand. Eel grass sparse.	0	0	0
45	4	Muddy sand. Widgeon grass and eel grass abundant.	0	0	0
46	7	Hard clay. No vegetation.	0	0	0
47	4	Sandy mud. Eel grass and widgeon grass sparse.	0	6	0
48	8	Sandy mud. Eel grass and widgeon grass sparse.	0	0	0
49	6	Sandy mud over clay. Trace eel grass.	0	0	0
50	4	Sandy mud over sand. No vegetation.	0	6	11
51	4	Soft sandy clay. Eel grass sparse.	0	0	6
52	5	Soft sandy clay. No vegetation.	0	0	0
53	5	Hard sand. Shells scarce. No vegetation.	0	0	0
54	4	Loose sand over clay. Widgeon grass sparse.	0	0	0
55	4	Clay. Trace widgeon grass.	0	0	0
56	3	Soft mud over clay. Eel grass sparse.	0	0	0
57	4	Muddy sand over clay. Trace widgeon grass.	0	0	9
58	5	Clayey sand. Trace widgeon grass.	0	0	46
59	5	Muddy sand over clay. Trace widgeon grass.	0	0	9
60	4	Hard clay. No vegetation.	0	0	0
61	4	Loose sand over clay. No vegetation.	0	0	0
62	6	Sandy clay. No vegetation.	0	0	0
63	4	Sandy clay. Eel grass sparse.	0	0	46
64	5	Clay. Trace of eel grass.	0	0	0
65	4	Hard clay. Widgeon grass sparse.	0	0	0

[1] Based on number of juvenile soft-shelled clams in sample and assuming all survive.

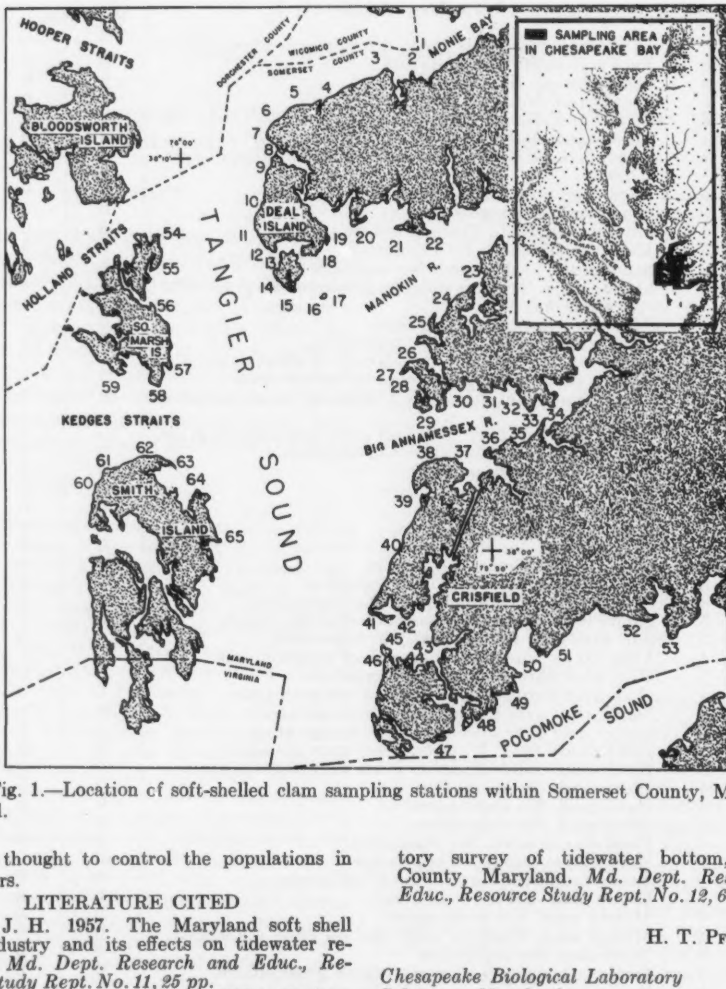

Fig. 1.—Location of soft-shelled clam sampling stations within Somerset County, Maryland.

stock are thought to control the populations in these waters.

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Additional Comments on Adult Bull Sharks *Carcharhinus leucas* (Müller and Henle), from Chesapeake Bay, Maryland[1]

ABSTRACT

Measurements comparable to those listed by Bigelow and Schroeder are recorded along with the proportional dimensions in percent of total length for an adult male and female bull shark, *Carcharhinus leucas*. These specimens were captured on successive days in the same pound net in Chesapeake Bay near Galesville, Maryland. Comments on gonad condition of the female, as well as the stomach contents, are included. Eels and white perch are added to the known food of this species. The pH of the stomach fluid was 3.7. Ten adult specimens have authentically been recorded

[1] Contribution No. 139, Maryland Department of Research and Education, Solomons, Maryland.

(1956–1959) 61 to 119 miles above the mouth of Chesapeake Bay. Although no general pattern of unusually high water temperatures or salinities was noted for these years, speculation on the appearance of this species this far north is proposed, linked to the increased warming oceanic waters.

Schwartz (1959) reported measurements of two adult male bull sharks, *Carcharhinus leucas* (Müller and Henle), from Chesapeake Bay. To date these are the only measurements of large *C. leucas*. Beebe and Tee Van (1933), Bigelow and Schroeder (1948), Jordan and Dickerson (1908), Jordan and Evermann (1896), Jordan and Gilbert (1882), Nichols and Breder (1927) and Springer (1950) noted maximum sizes and weights for this species, but only Fowler (1908) has contributed to the knowledge of size variation with maturity. Young specimens of about 1½–2½ foot lengths are noted by Baughman (1950), Jordan and Dickerson (1908), Nichols (1917) and Springer (1940) but no elaboration is made of body size and proportions. It is the purpose of this paper to present additional information on the dimensions, proportions, gonad condition and food of an adult male and female *C. leucas* as well as the distribution of this species as found in Chesapeake Bay, Maryland.

Measurements (Table 1) comparable to those listed by Bigelow and Schroeder (1948) and Schwartz (1959) are recorded here along with the proportional dimensions in percent of total length. Two adult bull sharks, *C. leucas*, were captured on successive days in a pound net operated by Captain Warren Hazzard at Broadwater Creek (2 miles SW of Franklin Point on Chesapeake Bay, Anne Arundel County), Maryland. On July 28, 1959, a female *C. leucas*, 2590 mm (8 feet, 6 inches long) weighing 328+ pounds, was captured after a fierce struggle in which it bit an oar in two and attacked the pound net fishermen. A docile male *C. leucas*, 2197 mm (7 feet, 2 inches long) weighing 202 pounds, was also captured in the same pound net on July 29, 1959. Schwartz (1959) notes a vicious male specimen captured in Chesapeake Bay at the Big Annemessex River. *C. leucas* is generally considered to be a slow, sluggish and docile species (Bigelow and Schroeder 1948), and is sometimes ridden by children as it frequents the shoals of Florida. However, the behavior described above (see photograph cited under *Oceanus*, 1957) would suggest that extreme caution should be exercised when encountering or handling this species.

Notable differences (Table 1) between these two specimens and those reported earlier (Schwartz 1959) were greater male and female trunk breadth and height, as well as female weight. Inadequate scales prevented accurate weighing of the female specimen (scales and pan limits were 328 pounds) but it obviously did not exceed 400 pounds. The remainder of the measurements for both specimens fell within the range already reported.

Gudger (1940) noted the gonad condition of a single adult female *C. platyodon* (= *leucas*, Bigelow and Schroeder, 1948) as, "The left ovary small and the right large with eggs in the an-

TABLE 1.—Dimensions and proportions in percent of total length for two bull Sharks, *Carcharhinus leucas*, from Chesapeake Bay.

Item	Broadwater Creek, Anne Arundel County			
	Female		Male	
	July 28, 1959		July 29, 1959	
	Measurement	Percent	Measurement	Percent
	(*in mm*)		(*in mm*)	
Trunk at origin pectoral				
a) breadth	530.0	20.5	360.0	16.4
b) height	535.0	20.7	430.0	19.6
Snout in front of outer				
a) nostrils	50.0.	1.9	45.0	2.0
b) mouth	130.0	5.0	120.0	5.5
Eye: Horizontal diameter	20.0	0.8	20.0	0.9
Mouth				
a) breadth	330.0	12.7	394.0	13.4
b) height	130.0	5.0	113.0	5.1
Nostrils between inner ends	169.0	6.5	136.0	6.2
Gill opening lengths				
a) 1st gill slit	100.0	3.9	70.0	3.2
b) 2nd gill slit	120.0	4.6	87.0	4.0
c) 3rd gill slit	116.0	4.5	91.0	4.1
d) 4th gill slit	106.0	4.1	90.0	4.1
e) 5th gill slit	77.0	3.0	70.0	3.2
Dorsal				
a) vertical height	302.0	11.7	240.0	10.9
b) base length	250.0	9.7	250.0	11.4
Second dorsal				
a) vertical height	98.0	3.8	68.0	3.1
b) base length	120.0	4.6	87.0	4.0
Anal				
a) vertical height	128.0	4.9	103.0	4.7
b) base length	107.0	4.1	90.0	4.1
Caudal				
a) upper margin	682.0	26.3	572.0	26.0
b) lower anterior margin	335.0	12.9	280.0	12.7
Pectoral				
a) outer margin	562.0	21.7	430.0	19.6
b) inner margin	143.0	5.5	122.0	5.6
c) distal margin	544.0	21.0	423.0	19.3
Distance snout to				
a) $dorsal_1$	813.0	31.4	663.0	30.2
b) $dorsal_2$	1740.0	67.2	1282.0	58.4
c) upper caudal	2000.0	77.2	1557.0	70.9
d) pectoral	565.0	21.8	482.0	21.9
e) pelvic	1440.0	55.6	1166.0	53.1
f) anal	1735.0	67.0	1477.0	67.2
Interspace between				
a) 1st and 2nd dorsal	570.0	22.0	507.0	23.1
b) 2nd dorsal and caudal	210.0	8.1	204.0	9.3
c) anal and caudal	145.0	5.6	140.0	6.4
Distance origin to origin				
a) pectoral and pelvic	698.0	26.9	557.0	25.4
b) pelvic and anal	409.0	15.7	290.0	13.2
Total length	2590.0		2197.0	
Teeth	$\frac{13\text{-}1\text{-}13}{12\text{-}1\text{-}12}$		$\frac{12\text{-}1\text{-}13}{12\text{-}1\text{-}12}$	

terior part." The present female specimen was devoid of eggs and the gonads were thin and minute. The gonads of the male specimen were about an inch wide and full of milt.

The female specimen's stomach was empty. That of the male contained 74 eels, *Anguilla rostrata*, of varying lengths to 3 feet, 4 white perch, *Roccus americanus*, and 2 croakers, *Micropogon undulatus*, constituted the food of the male. Nichols (1917) found large and small stingrays as food of *C. leucas* while black-tipped sharks, *Mobula*, shad, porpoise fins, crabs, mackerel (Bell and Nichols, 1921), sea urchin plates, vegetable matter (Linton, 1904), striped mullet, menhaden (*Brevoortia patronus*), croakers and white shrimp (Darnell 1958) have at times constituted the food of this indiscriminate feeder (Baughman and Springer, 1950). Schwartz (1959) cited attacks of *C. leucas* on the cownose ray, *Rhinoptera bonasus*, in Chesapeake Bay, however, stomach examinations have yet to reveal it as a food item.

Examination of Captain Hazzard's catch on July 28–29, 1959 revealed striped bass, *Roccus saxatilis*; gray sea trout, *Cynoscion regalis*; flounder *Paralichthys dentatus*; and menhaden, *B.*

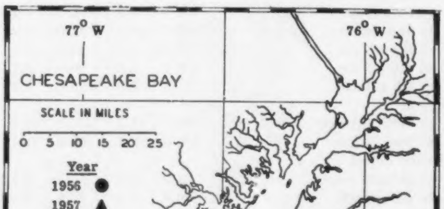

Fig. 1.—Known localities for 10 adult bull sharks, *Carcharhinus leucas*, captured within Chesapeake Bay, 1956 through 1959.

tyrannus. The net had been cleaned on the 28th, thus it is likely the male specimen, captured on the 29th, had eaten elsewhere. Even though digestion is rapid, the food items were still fresh and entire. The digestive fluid in the stomach possessed a pH of about 3.7 and produced reddening and blistering of bare hands within 5–10 minutes, while the author probed the body cavity.

The range of *C. leucas* is generally stated as the Gulf and Atlantic Coasts of Florida and through the West Indies from Texas to the Carolinas (Beebe and Tee Van, 1933; and Springer 1938, 1950) with strays to New Jersey and off Woods Hole, Massachusetts, (Fowler, 1907; Nichols, 1917; and Nichols and Breder, 1927). Baughman and Springer (1950) suggest that the center of abundance is in the West Indies—Caribbean region. Gunter (1938) and Myers (1952) cite this shark entering fresh water for considerable distances. Since 1956, a total of 10 specimens of this species have been captured in Chesapeake Bay waters of 4–14‰ salinity between Rock Hall and Crisfield, Maryland (Fig. 1). The salinity off Broadwater Creek where the current specimens were captured was approximately 10‰. It has been captured in only the upper portion of Chesapeake Bay, 61–119 miles above its mouth. It is strange if this species has escaped the many pound nets along Virginia's eastern and western shores of Chesapeake Bay. Speculation of a northerly extension of range with warming water temperature seems logical as a trend of increasing water and air temperatures has occurred in the Baltimore-Solomons area. Baltimore has experienced an increase of 1.8° C in air temperature during the past 100 years while Solomons has had a recorded water temperature increase of 0.27° C in 20 years. Water temperatures were, in comparison to a 20-year average, low to normal during the 1956–1959 summers, the 1957 and 1959 summer salinities were higher than normal while the 1956 and 1958 salinities were lower than normal.

It is a pleasure to acknowledge the generous assistance of Messrs. George J. Murphy and Ira Rubinoff while measuring the two specimens which were made available for study by Captain Warren Hazzard and the Woodfield Fish and Oyster Company, Galesville, Maryland. Thanks are due Mr. G. F. Beaven for access to the temperature and salinity data he has been assembling over the past 22 years for the Solomons area.

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Notes on the Soft-Shell Turtle (*Trionyx*) in Maryland Waters[1]

ABSTRACT

The capture of an adult eastern soft-shell turtle, *Trionyx ferox spinifera* (LeSueur), in brackish water of a branch of West River, a tributary of Chesapeake Bay, Anne Arundel County, Maryland, is regarded as an example of introduction by man from an out-of-state source. It has been doubtfully recorded from the Susquehanna River above the Maryland line. It may have occurred naturally in the Youghiogheny River in the Ohio drainage system in extreme western Maryland, but mine waste pollution may have exterminated it. Although introduced in the Potomac River at Cumberland, Maryland, from West Virginia over 75 years ago, the stocking was apparently unsuccessful. Except for the present record, there is no authoritative evidence that it is now present in Maryland.

Herpetological surveys in Maryland have not revealed the occurrence of any indigenous members of the soft-shell turtle family, *Trionychidae*. Thus, the record of an adult eastern spiny soft-shell turtle, *Trionyx ferox spinifera* (LeSueur), captured in tidewater at Ponder Cove, at the head of Rhode River, a branch of West River, Anne Arundel County, Maryland, is of special interest. It was taken by a crabber, Mr. John R. Christenson, on October 18, 1953, in slightly brackish water with a dip net, in a typical estuarine habitat known to support large crab populations. Although the blue crab, *Callinectes sapidus*, is known to migrate into fresh waters above tidewater limits, it is usually concentrated in areas having salinities above five parts per thousand. It is probable that the turtle was taken in this minimum salinity. Carr (1952:417) points out that the southern soft-shell turtle, *Trionyx f. ferox*, has been found in brackish waters, but he cites no records of the eastern soft-shell turtle entering saline waters. The latter's described range is entirely within the fresh water portions of the United States.

The specimen was taken on a muddy bottom in shallow water two or three feet deep. Although it was almost completely buried, the head and neck were outstretched. The animal was forced out of the mud with a crab net and thrown into the boat. It attempted to bite and moved about actively. The junior author first procured the specimen; later, it was turned over to Dr. Robert Simmons, a herpetologist living in Baltimore.

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[1] Contribution No. 140, Maryland Department of Research and Education, Solomons, Maryland.

This unusual record constitutes the only one known from the Coastal Plain of Maryland, but, as shown below, the specimen probably originated outside Maryland. McCauley (1945:26) stated: "*Amyda spinifera spinifera* (LeSueur) [=*Trionyx ferox spinifera*].—Roddy (1928, 19) says of this species that it 'may occur in the lower Susquehanna,' hence in Maryland. No specimens exist to bear this out." Roddy's study was concentrated in Lancaster County, Pennsylvania. Netting (1949:22) indicates that it has not been found authoritatively in the Susquehanna River. Probably Roddy's remarks were based on speculation or perhaps on some vague report of the introduction of soft-shell turtles.

The soft-shell turtle, therefore, is not known to occur naturally in the Chesapeake Bay drainage system. It is possible that the specimen may have been: (a) transported from somewhere in the Middle West and released here; (b) bought in a pet shop, kept for a number of years, and then released after it had reached adult size when they are vicious biters and dangerous; or, since it is highly esteemed as food for human consumption, (c) shipped from a commercial source out-of-state. In any event, its occurrence would be due to human transportation. With the present state of knowledge of the distribution of this species, the record cannot be listed as additional species for the state list.

Carr (1952:414) includes part of western Maryland in his general range map of *Trionyx ferox spinifera*. The records cited below are the only support for this general delineation. The range includes the section of extreme western Maryland that is within the Ohio drainage system. The most authentic record of its possible occurrence in the Ohio drainage waters of Maryland is based on the comments of Ortmann (1909:93). He remarked that the soft-shell turtle ("*Aspidonectes spinfer*" [=*Amyda ferox spinifera*]) was a good example of a species that had been killed off by pollution; "...It used to be present everywhere, but it has been exterminated practically in the Ohio, the lower Allegheny, the Monongahela and Youghiogheny. It is still present, for instance, in the clear waters of the upper Youghiogheny, the upper Allegheny, in Lake Erie, etc." The upper Youghiogheny, part of which is located on the Allegheny Plateau in Maryland, may have been unpolluted before 1909 in some locations, but for the last 40 years it has been devastated by acid mine wastes, eliminating the animal life in much of the main river system. In spite of Ortmann's comments, there are no specimens extant in museums or locality records of this species from the Youghiogheny system of Maryland. Since the species is occasionally seen in smaller streams, in spite of its proclivity for larger, slow-moving rivers, it is remotely possible that relic populations may exist in certain large tributaries of the Youghiogheny River. This may also be true in the Castleman River, which is relatively clean through much of its length in Maryland.

One of the most interesting experiments in the stocking of foreign animals in the waterways of Maryland concerned the introduction of the spiny soft-shell turtle in the Potomac River in 1883. Dukehart (1884:143) reported that 18 turtles were taken from the Ohio River near Moundsville, West Virginia, and placed in the Potomac River below the dam at Cumberland, Maryland, on August 25, 1883. None was subsequently reported from the river system; apparently, the population has died out, or, if it survived, members are so secretive that they have not been detected. Why they have not survived is unknown since the Potomac River habitat does not differ greatly from the place of origin. It is of interest to compare the turtle introduction to a classic parallel example of the stocking of an Ohio drainage fish, the northern small mouth bass, *Micropterus d. dolomieui*. The later were successfully transported from West Virginia, and perhaps from the Youghiogheny of Maryland, into the Potomac River. These prospered and spread throughout the Potomac River system above the Fall Line, but such has not been the case for the soft-shell turtle.

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Mass Mortality of the Starfish, *Asterias forbesi*, on the Atlantic Coast of Maryland[1]

ABSTRACT

Great numbers of the common starfish, *Asterias forbesi*, were washed ashore from the Atlantic Ocean along Worcester County, Maryland, during an unusually severe storm in February, 1960. Several millions were killed on the beach, while others survived. A length frequency distribution revealed a bimodal distribution, suggesting two age groups, as have been observed in more northern waters. Large numbers of surf clams, *Spisula solidissima*, were also washed ashore with the starfishes.

Numbers estimated into the millions of the common starfish, *Asterias forbesi*, were observed washed out of the Atlantic Ocean ashore onto the beaches of Maryland on February 5, 1960, after two days of strong northeast winds. Counts made in several localities along this stretch of coastline, which ranged from four to five miles above Ocean City Inlet to six or seven miles below the Inlet, indicated that at least several millions were killed on the beach. Reliable eyewitnesses reported that for a period of several hours at Ocean City the breakers were literally red with the bodies of starfishes as they were carried ashore. In some areas the beach was completely covered with the animals, many of which were still alive.

The author visited the beach the next morning, made spot counts, and collected 215 starfishes at random. The diameter of each specimen from the arm tips was measured to the nearest half centimeter. The length frequency distribution, with sizes which ranged from 55 to 230 mm, is shown in Fig. 1. A bimodal distribution is evident, indicating that two age groups are possibly represented. Mead (1901:220) and Galtsoff and Loosanoff (1939:84, 112) have pointed out that the size of starfishes is not an accurate indication of their age, for growth varies considerably depending on the amount of food consumed. Galtsoff and Loosanoff (1939:84–5) illustrated a similar bimodal length frequency distribution of *Asterias forbesi* taken in December and April in Long Island Sound. They remarked, "It is very probable that the 8–9 cm. class, which makes the first peak of the April curve, is formed by starfish less than one year old, and that the 13 cm. class, responsible for the second maximum, comprises older animals." The peaks near 10 and 17 cm in the present collection may correspond, since warmer temperatures and longer growing seasons occur along the Maryland coast. Little data are available on the age distribution and growth rates of this species in the Middle Atlantic region, although Cowles (1930:365) and Galtsoff and Loosanoff (1939:120–5) presented extensive data on the distribution of *Asterias forbesi* in lower Chesapeake Bay.

Asterias forbesi was very numerous at the Ocean City Inlet during the summer and fall of 1959, especially around the shore and docks. However, some evidence is available to indicate that it did not invade the small shallow bays where many oysters have been planted. In eight years of observation in this region, 1959 was the first period when such large numbers of starfishes were seen. Commercial fish trawlers commonly take large numbers in offshore waters, but during the past season the numbers have been so great that in some cases fishermen were forced to cease fishing because trawls became so filled with starfishes that they would no longer catch fish. Virtually all starfishes in trawl catches in this area are *Asterias forbesi*.

Great numbers of small surf clams, *Spisula solidissima*, ranging from 35 to 70 mm in length, were also washed ashore with the starfishes during the same storm. A sample could not be taken because gulls had carried away great numbers before the author surveyed the area. It is probable that the starfishes were feeding on the beds of surf clams that occur in commercial quantities in the ocean off the Maryland coast. Many small clams were found on the beach with the starfishes, indicating that they probably were in the same area that was disturbed by the waves of the storm which carried them ashore. The storm was exceptionally severe. Inasmuch as the surf clams are usually found in depths of 50 feet or more, it is interesting to speculate that the size and force of the waves that transported them from the bottom must have been great. The exact depth from

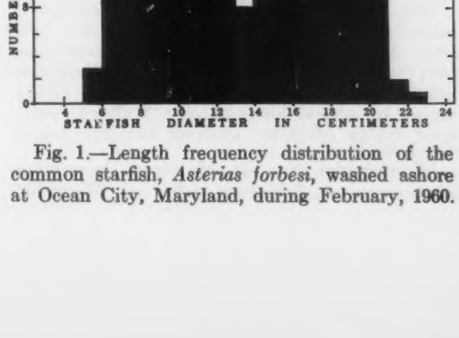

Fig. 1.—Length frequency distribution of the common starfish, *Asterias forbesi*, washed ashore at Ocean City, Maryland, during February, 1960.

[1] Contribution No. 141, Maryland Department of Research and Education, Solomons, Maryland.

which the clams originated, however, is unknown. None of the long-term local residents remembered observing so many starfishes and surf clams washed ashore on the beach, hence this occurrence is unusual.

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Availability of Striped Bass during Summers of 1958 and 1959 as Reflected in Commercial Haul Seine Catch[1]

ABSTRACT

An analysis of the Maryland summer haul seine fishing effort and landings of striped bass, *Roccus saxatilis*, for the years 1958 and 1959 shows a doubling in harvest with a reduction of one-sixth in seine days fished during 1959. It is concluded that striped bass were available in considerably greater numbers to this gear in 1959 than in 1958, and that the 1956 and 1957 year-classes probably contributed largely to these landings.

INTRODUCTION

Seine haulers in mid-Chesapeake Bay, Maryland, usually expend their fishing efforts during summer months in harvesting such migratory species as the Atlantic croaker, *Micropogon undulatus*, and spot, *Leiostomus xanthurus*. A few other licensees seine for carp, *Cyprinus carpio*, and catfish, *Ictalurus* species, in slightly brackish to tidal fresh waters. Striped bass, *Roccus saxatilis*, is usually taken as a buffer or incidental species. During 1958 and 1959, years of high availability of this species, haul seine landings during the summer season were also unusually high. The total landings by this gear in 1959 doubled those of 1958, as shown by the preliminary summaries based on 95 percent of all licensed fishermen returns (Murphy, 1958:1 and 1959:1). This analysis is an attempt to understand whether the increased catch is due to increased effort in 1959 over that of 1958, or to a real increase in availability of striped bass.

METHODS AND DEFINITIONS

The present paper is restricted to the total catch and fishing effort of one gear—the haul seine. This differs somewhat from the procedures used by Walburg (1955:5–6) and Walburg and Sykes (1957:12) in estimating fishing effort of one species by several kinds of gear. Walburg calculated fishing effort by applying net-days fished, based on a sample of Maryland fishermen, to the annual total catches for each kind of gear. His data had been extracted from the U. S. Fish and Wildlife Service tabulations of catch records collected by the Maryland Department of Research and Education.

The present statistics, based on 95 percent returns, were compiled from the raw data of individual reports. The monthly fishing effort was calculated from the total number of days fished by all seines in use. For 1959, some fragmentary data were supplied by a few fishermen on their daily number of hauls, but the lack of such information in 1958 precluded comparison. Such voluntary information became available through a redesigned catch form, first used in 1959. Thus, seine days were chosen as the principal measure of fishing effort. The term "seine days" is defined as the monthly grand total of the days fished by all seine haulers. "Catch per seine day" is defined as the quotient of Monthly catch/Seine days.

Tallies of the number of days fished and the total pounds of striped bass were made from the individual haul seine reports for the summer (July, August and September) period or third quarters of 1958 and 1959. Monthly totals were compiled from these individual tallies. Each monthly report was considered as from one haul seine. Third quarter totals of pounds landed and of number of days fished were the sums of the three respective monthly totals. The number of seines in quarterly use was an average, weighted for days fished, of the seines used monthly.

DISCUSSION AND RESULTS

In 1958, 45 summer haul seines (weighted average) caught a total of about 213,000 pounds of striped bass, while in 1959, 39 haul seines (weighted average) caught a total of more than 437,000 pounds of this species. Actual number of seine days of fishing for the period was 912 in 1958 and 763 in 1959. Monthly comparisons for both years of total effort, total catch and catch per unit effort are given in Fig. 1.

[1] Contribution No. 142, Maryland Department of Research and Education, Solomons, Maryland.

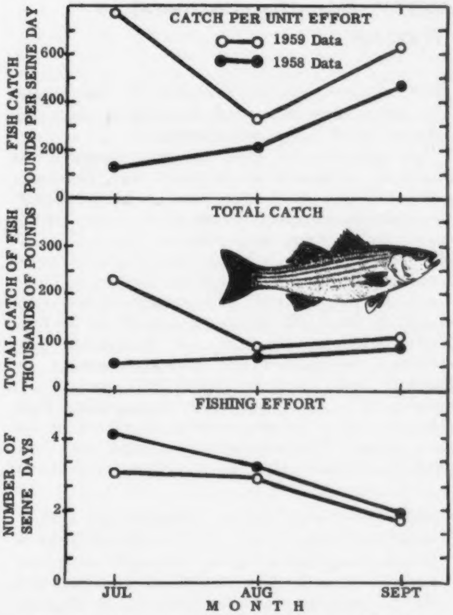

Fig. 1.—Comparison of total fishing effort, total catch, and catch per unit effort, of striped bass, *Roccus saxatilis*, by commercial haul seines during summer 1958 and 1959 in Chesapeake Bay, Maryland. Graph represents hundreds of seine days.

Apparently the 1959 striped bass fishery was supported by one or more unusually large year-classes. A clue to which year-classes might be involved is afforded by the designation of size categories for striped bass in the 1959 catch records from licensed fishermen. About three-fourths of total pounds landed in the summer of 1959 were reported by sizes. The percentage composition by size of striped bass caught by haul seines was: small—33, medium—14 and large—30. The approximate year-classes included in the catches were: small and medium sizes—1956 and 1957, and large—1955 and earlier broods. The percentage of fish in the small (12–14 inch size) category was relatively large, while that of the medium (14–17 inch sizes) was low. Thus, it is probable that one or two age groups contributed to the large catches of young fish. The large category (17 inches up) includes a wider range of sizes than either small or medium and also a larger number of year-classes. Crude identifications of year-classes were made according to the lengths given by Mansueti (1955:2) and unpublished data. From these estimations, it is probable that the 1957 and small-sized individuals from the 1956 year-classes supported the large catches made in the summer haul-seine fishery.

The caution stated in Rounsefell and Everhart (1953:78) against crediting fishing effort directed primarily for one species to another must be applied to this seasonal fishery. As stated above, Maryland summer seine haulers engage in a mixed fishery. It is probable that most of the seiners started fishing for their traditional summer species, i.e., Atlantic croaker, spot, carp and catfish. It is further assumed that when some of these species did not appear in quantities large enough for profitable operations, the total fishing effort by haul seines decreased. Although these fishing efforts were not expended exclusively for striped bass but for other species as well, the low availability of the latter apparently reversed the principal effort toward striped bass.

CONCLUSIONS

Although overall activities of seine haulers in summer 1959 declined by one-sixth from 1958, measured in seine days fished, a comparison of the striped bass catches for both summers shows that landings doubled in 1959. It is probable that a doubling of total catch, by one kind of gear, in a particular season with an accompanying stable fishing effort was due to an increased availability of the species, when two succeeding years were compared. Secondly, it is assumed that a doubling of total catch, accompanied by a drop in fishing effort, when the same seasons for two succeeding years were compared, would indicate a strong possibility of a dominant year-class contributing to the catch. The age composition of the summer catch indicated the possibility of two dominant year-classes, 1957 or 1956. Other evidence discounts the strong effect of 1957 hatched fish and points toward the 1956 year-class as being the dominant one that contributed to the large catches.

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Comments on the Roughtail Stingray, *Dasyatis centroura*, in Maryland Waters[1]

ABSTRACT

The roughtail stingray, *Dasyatis centroura*, is recorded from Chesapeake Bay, Maryland, for the first time. The specimen, an average-sized adult female, was 35¼ inches broad and weighed 56 pounds. The reproductive tract contained three large heavily yolked eggs in the left ovary and the specimen probably had just become sexually mature. The stomach contained parts of spot and menhaden and other fish remains.

Although Uhler and Lugger (1876:187) reported the occurrence of the roughtail stingray, *Dasyatis centroura* (Mitchill), at the mouth of Chesapeake Bay in Virginia, and along the Atlantic Coast of Maryland, Hildebrand and Schroeder (1928:64) remarked that "This ray probably was not taken during the present investigation and no specimens are at hand." Subsequently, Bigelow and Schroeder (1953:361–362) cited many published records of this species throughout its range; no additional records for the Maryland region were given, except to cite Truitt, Bean and Fowler (1929:31) who listed it from Chesapeake Bay, probably by reference to Uhler and Lugger's statement. Bigelow and Schroeder (1953:362), incidentally, placed the latter reference among their doubtful synonyms and references. Thus, the positive identification of *D. centroura* in the Maryland part of Chesapeake Bay is worthy of record.

An adult female, 35¼ inches broad and weighing 56 pounds, was hooked in Chesapeake Bay off Long Point, Dorchester County, Maryland, on September 7, 1959, by Captain Carl Breland of Solomons, Maryland. Four species of *Dasyatis* are known to occur in Chesapeake Bay (*D. centroura, D. americana, D. sabina* and *D. say*), and *D. centroura* far exceeds the other three species in size. In addition to the characteristic large size of the present specimen (Bigelow and Schroeder 1953:343–345), the thorny tail and distribution of the mid-dorsal and peripheral tubercles provided further key features for positive identification. The possibility of confusing it with *D. americana* was obviated by the very narrow ventral tailfold of the specimen under study. About 65 teeth were counted on each side of the spine of the Maryland specimen, whereas Bigelow and Schroeder (1953:355) recorded about 40 along the distal two-thirds. Measurement data based on methods outlined by Bigelow and Schroeder (1953:3–4) are given in Table 1, where it is compared with data for a smaller female given by these authors (p. 353). The total length of the Maryland specimen was 1650 mm while the body length and tail length (from center of cloaca) were 790 and 860 + mm. The latter measurement is incomplete since the extreme tip of the tail was missing.

The reproductive tract of this specimen was dissected, inasmuch as Bigelow and Schroeder (1953:358) indicated that little is known about the early developmental stages. The ovary, about seven inches long, was removed from the left side and contained many developing oocytes ranging from ⅛ to ½ inch in diameter. Three large, heavily yolked and orange-colored ova, measured 30 × 32, 30 × 33, and 28 × 30 mm. Embryos apparently had not developed. This specimen exemplified the general comment by Bigelow and Schroeder (1953:383) that "...it appears to be the general rule among Sting Rays that only one of the two ovaries and uteri function at a time." The best evidence cited by these authors indicates that *D. centroura* apparently

TABLE 1.—Comparison of proportional dimensions in percent of extreme breadth of disks of female roughtail stingrays, *Dasyatis centroura*, from Chesapeake Bay, Maryland, and Buzzards Bay, Massachusetts (the latter from Bigelow and Schroeder, 1953:353).

Body Feature Measured	Maryland Specimen		Massachusetts Specimen
	Measurement in Millimeters	Percent of Extreme Breadth of Disk	Percent of Extreme Breadth of Disk
Breadth of disk	895	100.0	100.0 (610 mm)
Vertical length of disk	710	79.3	82.3
Snout length in front of orbits	230	25.7	17.0
Snout length (front of mouth)	189	21.1	18.9
Orbits (horizontal diameter)	22	2.5	4.9
Orbits (distance between)	72	8.0	10.0
Spiracles (length)	57	6.4	6.2
Spiracles (distance between)	136	15.2	16.2
Mouth (breadth)	98	10.9	8.4
Nostrils exposed (distance between)	85	9.5	10.6
Gill openings (lengths)			
One	26	2.9	3.3
Three	30	3.3	2.9
Five	18	2.5	2.2
Gill openings (distance between inner ends)			
One	—	—	18.9
Five	—	—	12.8
Pelvics (anterior margin)	142	15.9	15.9
Snout tip to cloaca center	740	82.7	73.0
Cloaca center to origin of caudal spine	370	41.3	40.0
Spine (length from origin)	96	10.7	—
Weight in pounds	56	—	—

[1] Contribution No. 143, Maryland Department of Research and Education. Solomons, Maryland.

does not become sexually mature until it attains a breadth of four feet or more, and that "... the great majority of specimens that have been studied, i.e., up to 40–56 inches wide, have been immature." (p. 357). It is possible that the specimen under study may have become sexually mature for the first time because of the absence of embryos and the presence of large yolked eggs. In their comments of *D. say*, Bigelow and Schroeder (1953:383) point out that "...eggs 12–15 mm in diameter have been found in a female which at the same time had embryos of the next older generation nearly ready for birth." No date was given for this phenomenon, nor is the period of gestation known for *D. say*.

The stomach was dissected in this specimen, and the anterior part of a medium-sized spot, *Leiostomus xanthurus*, the posterior part of a medium-sized menhaden, *Brevoortia tyrannus*, and miscellaneous fish bones were observed. Bigelow and Schroeder (1953:358) summarized the knowledge of the food habits of this species, and cited invertebrates as the preferred food. They commented that it bites readily on various kinds of bait including fish. It is difficult to say whether the fish found in the stomach of the specimen under study was bait, or scavenged from the bottom, or caught as prey. Anglers in Chesapeake Bay near where this specimen was captured reported that stingrays were readily taking various kinds of baits especially those used for cobia, *Rachycentron canadus*, which were being caught at the same time.

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Cowles, R. P. 1930. A biological study of the offshore waters of Chesapeake Bay. *Bull. U. S. Bur. Fish. 46 (1091): 277–381.*

Brooks, W. K. 1905. The oyster: a popular summary of a scientific study. *Johns Hopkins Univ. Press, Balto. xvi + 225.*

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